Bacteria Total Maximum Daily Load Development for Pigg River, Snow Creek, Story Creek, and Old Womans Creek

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Chapter 1: Executive Summary

1.1. Background

Five TMDLs are presented in this report: Old Womans Creek (VAW-L13R-01, 4.86 miles); Snow Creek (VAW-L17R-01, 10.98 miles); Story Creek (VAW-L14R-02, 11.6 miles); Upper Pigg River (VAW-L14R-01, 35.06 miles); and Leesville Lake-Pigg River (VAW-L13L-02, 154 acres). The Story Creek and Upper Pigg River watersheds are located entirely within Franklin County; the Snow Creek and Leesville Lake-Pigg River watersheds are in both Franklin and Pittsylvania Counties; and Old Womans Creek is located entirely within Pittsylvania County. Story Creek, Upper Pigg River, and Snow Creek are tributaries to Leesville Lake-Pigg River, which in turn is a tributary to Leesville Lake. Throughout this report, a reference to 'Pigg River' without a qualification as to which part indicates that the entire watershed (including Snow Creek and Story Creek) is being referenced. Old Womans Creek also discharges to Leesville Lake. Leesville Lake is on the Roanoke River (USGS Hydrologic Unit Code 02070005), which flows into the Albemarle Sound; the Albemarle Sound discharges to the Atlantic Ocean.

As a point of clarification, 'Leesville Lake – Pigg River' was originally listed as part of VAW-L18R based on monitoring data from station 4APGG003.29. In the 2004 assessment, this segment was listed as part of VAW-L13L. Additionally, the two segments VAW-L15R-01 (Big Chestnut Creek) and VAW-L18R-01 (Pigg River) are encompassed by the Pigg River watershed; although TMDL equations were not explicitly defined for these two reaches, the successful allocation scenarios for the entire basin include reductions in the watersheds contributing to these two impaired segments.

1.2. Bacteria Impairment

1.2.1. Background

Water quality samples collected on the impaired segments during the 2004 Assessment Period yielded impaired results as shown in Table 1.1. The interim instantaneous freshwater water quality standard for fecal coliform specifies that fecal coliform concentration in the stream water should not exceed 400 colony forming units (cfu) per 100 mL; the instantaneous standard for *Escherichia coli* specifies that the *E. coli* concentration should not exceed 235 cfu/100 mL. Due to the frequency of water quality violations at the stations listed in Table 1.1, Snow Creek, Story Creek, Pigg River, and Old Womans Creek remained on Virginia's 2004 303(d) list of impaired water bodies for fecal coliform. These impaired segments have been assessed as not supporting the Clean Water Act's Primary Contact Recreational Use Goal. Story Creek and Upper Pigg River have been on the impaired waters list since 1996; Leesville Lake-Pigg River has been on the list since 1998; and Snow Creek and Old Womans Creek have been on the list since 2002. The details of the fact sheet listings are given in Table 1.2.

Table 1.1. Bacteria standard exceedances during the 2004 assessment period (1998-2002).

Station ID	Exceedances of Interim Fecal Coliform Standard
4ASDA009.79	13 of 24 (54%)
4ASNW000.60	3 of 17 (18%)
4APGG003.29	4 of 18 (22%)
4APGG030.62	7 of 27 (26%)
4APGG052.73	15 of 57 (26%)
4AOWC005.36	3 of 17 (18%)

Table 1.2. Impaired Segments Addressed in this TMDL report.

Impaired Segment	Size	Target Date for TMDL Development	Description
Old Womans Creek	4.86 miles	2010	Headwaters (end of perennial section) to Old Womans Creek mouth on Roanoke River
Snow Creek	10.98 miles	2010	Snow Branch/Ditto Branch Confluence to Snow Creek mouth on Pigg River
Story Creek[1]	11.6 miles	2010	Intersection of Rt. 40 and Rt. 748 to Story Creek mouth on Pigg River
Upper Pigg River	35.06 miles	2006	South Prong Pigg River mouth on Pigg River to 10 miles downstream of the Rocky Mount STP
Leesville Lake-Pigg River	154 acres	2010	Backwaters of Leesville Lake on Pigg River to Pigg River confluence with Roanoke River

[1]DEQ Fact Sheets list this stream as 'Storey Creek', but stakeholders corrected the spelling to 'Story Creek'

In order to remedy the fecal coliform water quality impairments, Total Maximum Daily Loads (TMDLs) have been developed, taking into account all sources of bacteria and a margin of safety (MOS). The TMDLs were developed for the new water quality standard for bacteria, which states that the calendar-month geometric mean concentration of *E. coli* shall not exceed 126 cfu/100 mL, and that no single sample can exceed a concentration of 235 cfu/100mL. A glossary of terms used in the development of these TMDLs is listed in Appendix A.

1.2.2. Sources of Bacteria

There are three point sources permitted to discharge bacteria into the Pigg River basin; one of these is located in the Story Creek portion of the watershed. No permitted facilities exist in the Old Womans Creek watershed. However, the majority of the bacteria load originates from nonpoint sources. The nonpoint sources of bacteria are mainly agricultural and include land-applied animal waste and manure deposited on pastures by livestock. A significant bacteria load comes from cattle and wildlife directly depositing feces in streams. Wildlife also contribute to bacteria loadings on all land uses, in accordance with the habitat range for each species. Non-agricultural nonpoint sources of bacteria loadings include straight pipes, failing septic systems, and pet waste. The amounts of bacteria produced in different locations (e.g., confinement, pasture, forest) were estimated on a monthly basis to account for seasonal variability in wildlife behavior and livestock production and practices. Livestock management and production factors, such as the fraction of time cattle spend in confinement, pastures, or streams; the amount of manure storage; and spreading schedules for manure application, were considered on a monthly basis.

1.2.3. Modeling

The Hydrological Simulation Program – FORTRAN (HSPF) (Bicknell et al., 2001) was used to simulate the fate and transport of fecal coliform bacteria in the Pigg River and Old Womans Creek watersheds. As recommended by VADEQ, water quality modeling was conducted with fecal coliform inputs, and then a translator equation was used to convert the output to *E. coli* for the final TMDL. To identify localized sources of fecal coliform within the watershed, the Pigg River watershed was divided into 23 sub-watersheds (including 2 for Story Creek and 4 for Snow Creek), based on homogeneity of land use, stream network connectivity, and monitoring station locations. The Old Womans Creek watershed was likewise divided into 7 sub-watersheds.

The hydrology component of HSPF was calibrated using flow data from September 1, 1989 to December 31, 1995; it was validated using data from June 1, 1984 to August 31, 1989. Initial estimates of hydrologic parameters were generated according to the guidance in BASINS Technical Note 6 (USEPA, 2000a). These parameters were refined during calibration. The program Expert System for the Calibration of HSPF (HSPEXP) was used to aid in calibration, and after the successful calibration the default calibration criteria in HSPEXP were met for both the calibration and validation periods.

The water quality component of the HSPF model was calibrated and validated for Pigg River, its tributaries, and Old Womans Creek at 10 monitoring stations. The bacteria model was calibrated to data from 7 stations (those seven having data during the calibration period) for a rough period of 1994-1998. The bacteria model was validated to data from all 10 stations for a rough period of 1999-2005. Inputs to the model included fecal coliform loadings on land and in the stream. A comparison of simulated and observed fecal coliform loadings in the stream indicated that the model adequately simulated the fate and transport of fecal coliform bacteria.

1.2.4. Margin of Safety

A margin of safety (MOS) was included to account for any uncertainty in the TMDL development process. There are several different ways that the MOS could be incorporated into the TMDL (USEPA, 1991). For Snow Creek, Story Creek, Upper Pigg River, Leesville Lake-Pigg River, and Old Womans Creek, the MOS was implicitly incorporated into the TMDL by conservatively estimating several factors affecting bacteria loadings, such as animal numbers, bacteria production rates, and contributions to streams. Points of particularly conservative estimates are pointed out throughout the text.

1.2.5. Existing Conditions

Contributions from various sources in the Pigg River and Old Womans Creek watersheds were represented in HSPF to establish the existing conditions for a representative 5-year period that included both low and high-flow conditions. Meteorological data from 1994-1998 were paired with bacterial loading and land use data for existing conditions to establish this baseline scenario. Results from the calibrated HSPF model showed varying contributions to the existing concentrations in the Pigg River watershed and its tributaries, with routine high signatures from livestock direct deposit, wildlife direct deposit, and pervious land surfaces. Concentrations in the Old Womans Creek watershed were dominated by wildlife direct deposit sources, with a slightly smaller signature from livestock direct deposit sources.

1.2.6. TMDL Allocations and Stage 1 Implementation

Monthly bacteria loadings to different land use categories were calculated for each sub-watershed in each watershed for input into HSPF based on amounts of bacteria produced in different locations. Bacteria content of stored waste was adjusted to account for die-off during storage prior to land application. Similarly, bacteria die-off on land was taken into account, as was the reduction in bacteria available for surface wash-off due to incorporation following waste application on cropland. Direct seasonal bacteria loadings to streams by cattle were calculated for pastures adjacent to streams. Bacteria loadings to streams and land by wildlife were estimated for several species. Bacteria loadings to land from failing septic systems were estimated based on number and age of houses. Bacteria contribution from pet waste was also considered.

When developing a bacteria TMDL, the required bacteria load reductions are modeled by decreasing the amount of bacteria applied to the land surface. In the model, this has the effect of reducing the amount of bacteria that reaches the stream, the ultimate goal of the TMDL. Thus, the reductions called for in Table 1.3 in the next section indicate the need to decrease the amount of bacteria reaching the stream in order to meet the applicable water quality standard. The reductions shown are not intended to infer that agricultural producers should reduce their herd size, or limit the use of manures as fertilizer or soil conditioner. Rather, it is assumed that the required reductions from affected agricultural source categories (cattle direct deposit, cropland, etc.) will be accomplished by implementing BMPs like filter strips, stream fencing, and off-stream watering; and that required reductions from residential source categories will be accomplished by repairing aging septic systems, eliminating straight pipe discharges, and other appropriate measures included in the TMDL Implementation Plan.

For the TMDL allocation scenarios, a target of zero violations of both the instantaneous and geometric mean water quality standards was used. For the Stage 1 implementation scenario, a target of zero reductions in wildlife and 10% violation of the instantaneous standard was used.

1.2.7. Allocation Scenarios

Different source reduction scenarios were evaluated to identify implementable scenarios that meet both the calendar-month geometric mean *E. coli* criterion (126 cfu/100 mL) and the single sample maximum *E. coli* criterion (235 cfu/100 mL) with zero violations. These scenarios were conducted using meteorological data from 1994-1998 to represent a variety of high and low flow conditions. The bacteria loadings used in modeling correspond to anticipated future conditions for the Pigg River watershed. The future conditions were determined by analyzing information from the Franklin County Comprehensive Plan currently under development. The reductions required for each impaired segment are presented in Table 1.4.

Equation [1.1] was used to calculate the TMDL allocation shown in Table 1.4.

$$TMDL = \Sigma WLA + \Sigma LA + MOS \qquad [1.1]$$

where:

WLA = wasteload allocation (point source contributions);

LA = load allocation (nonpoint source contributions); and

MOS = margin of safety.

Table 1.3. Successful allocation scenarios.

Impaired Watershed	Required Fecal Coliform Loading Reductions to Meet the *E coli* Standards,%					
	Cattle DD*	Loads from Cropland	Loads from Pasture	Wildlife DD*	Straight Pipes	Loads from Residential
Snow Creek	60	0	95	0	100	95
Story Creek	100	0	85	45	100	75
Upper Pigg River†	100	0	95	5	100	90
Leesville Lake – Pigg River‡	100	0	95	30	100	90
Old Womans Creek	100	0	90	67	n/a	85

*DD = direct deposit

†Includes reductions for Story Creek applied to the Story Creek portion of the watershed

‡Includes reductions for Story Creek, Snow Creek, and Upper Pigg River applied to the appropriate portions of the watershed

n/a = not applicable; no straight pipes exist in the Old Womans Creek watershed

There are three small point sources discharging at or below their permit requirements; therefore, the proposed scenario requires load reductions only for nonpoint sources of fecal coliform. The TMDL was determined as the average annual *E. coli* load at the watershed outlet for the chosen allocation scenarios. The WLA was obtained by taking the product of the permitted point source's *E. coli* discharge concentration and allowable annual discharge. The WLA for watersheds without permitted facilities was determined as <1% of the total TMDL load. The LA is then determined as the TMDL-WLA.

Table 1.4. Annual *E. coli* loadings (cfu/yr) for the TMDLs.

Impaired Segment	ΣWLA	ΣLA	MOS*	TMDL
Snow Creek	<1%	8.47×10^{13}	--	8.60×10^{13}
Story Creek	6.99×10^{11}	1.86×10^{13}	--	1.93×10^{13}
Upper Pigg River†	<1%	4.86×10^{13}	--	4.91×10^{13}
Leesville Lake – Pigg River‡	3.51×10^{12}	1.91×10^{14}	--	1.94×10^{14}
Old Womans Creek	<1%	7.17×10^{12}	--	7.24×10^{12}

*Implicit MOS
†Loads excluding those from Story Creek
‡Loads excluding those from Story Creek, Snow Creek, and Upper Pigg River

1.2.8. Stage 1 Implementation

The implementation of a transitional scenario, or Stage 1 implementation, will allow for an evaluation of the effectiveness of management practices and accuracy of model assumptions through data collection. Stage 1 implementation was developed without reductions for wildlife; a target of a 10% violation rate of the single sample *E. coli* water quality standard (235 cfu/100 mL) was used where the elimination of wildlife reductions did not prohibit it.

The Stage 1 scenarios for Snow Creek, Story Creek, Upper Pigg River, Leesville Lake-Pigg River, and Old Womans Creek are given in Table 1.5.

Table 1.5. Allocation scenarios for Stage 1 implementation for the impaired segments.

Impaired Segment	Single Sample Standard Percent Violation	Required Fecal Coliform Loading Reductions to Meet the Stage 1 Goal, %					
		Live-stock DD	Loads from Cropland	Loads from Pasture	Wildlife DD	Straight Pipes	Loads from Residential
Snow Creek	9	5	0	0	0	100	0
Story Creek	8	90	0	0	0	100	0
Upper Pigg River*	9	65	0	0	0	100	0
Leesville Lake - Pigg River†	10	10	0	0	0	100	0
Old Womans Creek	9	100	0	90	0	n/a	85

*Includes reductions for Story Creek applied to the Story Creek portion of the watershed
†Includes reductions for Story Creek, Snow Creek, and Upper Pigg River applied to the appropriate portions of the watershed
n/a = not applicable; no straight pipes exist in the Old Womans Creek watershed

1.3. Reasonable Assurance of Implementation

1.3.1. Follow-Up Monitoring

Following the development of the TMDL, the Department of Environmental Quality (DEQ) will make every effort to continue to monitor the impaired stream in accordance with its ambient monitoring program. DEQ's Ambient Watershed Monitoring Plan for conventional pollutants calls for watershed monitoring to take place on a rotating basis, bi-monthly for two consecutive years of a six-year cycle. In accordance with DEQ Guidance Memo No. 03-2004, during periods of reduced resources, monitoring can temporarily discontinue until the TMDL staff determines that implementation measures to address the source(s) of impairments are being installed. Monitoring can resume at the start of the following fiscal year, next scheduled monitoring station rotation, or where deemed necessary by the regional office or TMDL staff, as a new special study.

The purpose, location, parameters, frequency, and duration of the monitoring will be determined by the DEQ staff, in cooperation with DCR staff, the Implementation Plan Steering Committee, and local stakeholders. Whenever possible, the location of the follow-up monitoring station(s) will be the same as the listing station. At a minimum, the monitoring station must be representative of the original impaired segment. The details of the follow-up monitoring will be outlined in the Annual Water Monitoring Plan prepared by each DEQ Regional Office. Other agency personnel, watershed stakeholders, etc. may provide input on the Annual Water Monitoring Plan. These recommendations must be made to the DEQ regional TMDL coordinator by September 30 of each year.

DEQ staff, in cooperation with DCR staff, the Implementation Plan Steering Committee, and local stakeholders, will continue to use data from the ambient monitoring stations to evaluate reductions in pollutants ("water quality milestones" as established in the Implementation Plan), the effectiveness of the TMDL in attaining and maintaining water quality standards, and the success of implementation efforts. Recommendations may then be made, when necessary, to target implementation efforts in specific areas and continue or discontinue monitoring at follow-up stations.

In some cases, watersheds will require monitoring above and beyond what is included in DEQ's standard monitoring plan. Ancillary monitoring by citizens, watershed groups, local government, or universities is an option that may be used in such cases. An effort should be made to ensure that ancillary monitoring follows established QA/QC guidelines in order to maximize compatibility with DEQ monitoring data. In instances where citizens' monitoring data are not available and additional monitoring is needed to assess the effectiveness of targeting efforts, TMDL staff may request of the monitoring managers in each regional office an increase in the number of stations or monitor existing stations at a higher frequency in the watershed. The additional monitoring beyond the original bimonthly single station monitoring will be contingent on staff resources and available laboratory budget. More information on citizen monitoring in Virginia and QA/QC guidelines is available at http://www.deq.virginia.gov/cmonitor/.

To demonstrate that the watershed is meeting water quality standards in watersheds where corrective actions have taken place (whether or not a TMDL or TMDL Implementation Plan has been completed), DEQ must meet the minimum data requirements from the original listing station or a station representative of the originally listed segment. The minimum data requirement for conventional pollutants (bacteria, dissolved oxygen, etc) is bimonthly monitoring for two consecutive years. For biological monitoring, the minimum requirement is two consecutive samples (one in the spring and one in the fall) in a one year period.

1.3.2. Regulatory Framework

The goal of the TMDL program is to establish a three-step path that will lead to attainment of water quality standards. The first step in the process is to develop TMDLs that will result in attainment of water quality standards. This report represents the culmination of that effort for the bacteria impairment on Snow Creek, Story Creek, Upper Pigg River, Leesville Lake-Pigg River, and Old Womans Creek. The second step is to develop a TMDL implementation plan. The final step is to implement the TMDL implementation plan and to monitor stream water quality to determine if water quality standards are being attained.

While section 303(d) of the Clean Water Act and current EPA regulations do not require the development of TMDL implementation plans as part of the TMDL process, they do require reasonable assurance that the load and wasteload allocations can and will be implemented. EPA also requires that all new or revised National Pollutant Discharge Elimination System (NPDES) permits must be consistent with the TMDL WLA pursuant to 40 CFR §122.44 (d)(1)(vii)(B). All such permits should be submitted to EPA for review.

Additionally, Virginia's 1997 Water Quality Monitoring, Information and Restoration Act (WQMIRA) directs the State Water Control Board to "develop and implement a plan to achieve fully supporting status for impaired waters" (Section 62.1-44.19.7). WQMIRA also establishes that the implementation plan shall include the date of expected achievement of water quality objectives, measurable goals, corrective actions necessary and the associated costs, benefits and environmental impacts of addressing the impairments. EPA outlines the minimum elements of an approvable implementation plan in its 1999 "Guidance for Water Quality-Based Decisions: The TMDL Process." The listed elements include implementation actions/management measures, timelines, legal or regulatory controls, time required to attain water quality standards, monitoring plans and milestones for attaining water quality standards.

Watershed stakeholders will have opportunities to provide input and to participate in the development of the implementation plan, which will also be supported by regional and local offices of DEQ, DCR, and other cooperating agencies.

Once developed, DEQ intends to incorporate the TMDL implementation plan into the appropriate Water Quality Management Plan (WQMP), in accordance with the Clean Water Act's Section 303(e). In response to a Memorandum of Understanding (MOU) between EPA and DEQ, DEQ also submitted a draft Continuous Planning Process to EPA in which DEQ commits to regularly updating the WQMPs. Thus, the WQMPs will be, among other things, the repository for all TMDLs and TMDL implementation plans developed within a river basin.

1.3.3. Implementation Funding Sources

Cooperating agencies, organizations and stakeholders must identify potential funding sources available for implementation during the development of the implementation plan in accordance with the "Virginia Guidance Manual for Total Maximum Daily Load Implementation Plans". Potential sources for implementation may include the U.S. Department of Agriculture's Conservation Reserve Enhancement and Environmental Quality Incentive Programs, EPA Section 319 funds, the Virginia State Revolving Loan Program, Virginia Agricultural Best Management Practices Cost-Share Programs, the Virginia Water Quality Improvement Fund, tax credits and landowner contributions. The TMDL Implementation Plan Guidance Manual contains additional information on funding sources, as well as government agencies that might support implementation efforts and suggestions for integrating TMDL implementation with other watershed planning efforts.

1.4. Public Participation

Public participation was elicited at every stage of TMDL development in order to receive inputs from stakeholders and to apprise the stakeholders of the progress made. In Summer 2004 (Pigg River), Fall 2003 (Old Womans Creek), and January 2006 (Old Womans Creek), members of the Center for TMDL and Watershed Studies at Virginia Tech traveled to Franklin and/or Pittsylvania Counties to become acquainted with the watersheds. Throughout the process, personnel from Virginia Tech contacted stakeholders and local agency personnel via telephone and in person to acquire their input. Three public meetings were held. The first public meeting was held on August 16, 2005 at the W.E. Skelton Conference (4-H) Center in Wirtz, Virginia; due to low attendance, a second first public meeting, with the same content, was held on October 27, 2005 at Sontag Elementary School in Rocky Mount, Virginia. Both meetings informed the stakeholders of the TMDL development process and solicited feedback on initial estimates of watershed characteristics. The final report was presented at the final public meeting held on March 9, 2006 at Sontag Elementary School.

One kickoff meeting and two Technical Advisory Committee meetings were also held, on May 25, 2005; January 18, 2006; and February 15, 2006, respectively. These meetings gathered a group of interested stakeholders and agency personnel who provided more detailed feedback on the estimates and methods used in these TMDLs.

Chapter 2: Introduction

2.1. Background

2.1.1. TMDL Definition and Regulatory Information

Section 303(d) of the Federal Clean Water Act and the U.S. Environmental Protection Agency's (USEPA) Water Quality Planning and Management Regulations (40 CFR Part 130) require states to identify water bodies that violate state water quality standards and to develop Total Maximum Daily Loads (TMDLs) for such water bodies. A TMDL reflects the total pollutant loading a water body can receive and still meet water quality standards. A TMDL establishes the maximum allowable pollutant loading from both point and nonpoint sources for a water body, allocates the load among the pollutant contributors, and provides a framework for taking actions to restore water quality.

2.1.2. Impairment Listing

Old Womans Creek (VAW-L13R-01), Snow Creek (VAW-L17R-01), Story Creek (VAW-L14R-02), and three segments of Pigg River (VAW-L14R-01, VAW-L-18R-01, VAW-L13L-02) are listed as impaired on Virginia's 2004 Section 303(d) Total Maximum Daily Load Priority List and Report (VADEQ, 2004) due to water quality violations of the bacteria standard. Of these, Story Creek (VAW-L17R-01), Upper Pigg River (VAW-L14R-01), Leesville Lake-Pigg River (VAW-L13L-02), and Lower Pigg River (VAW-L18R-01) have been on the list since at least 1998. The Virginia Department of Environmental Quality (VADEQ) has described the impaired segments as presented in Table 2.1. In addition to the impairments listed in Table 2.1 for which this TMDL was specifically developed, the drainage area for Pigg River includes the Lower Pigg River (VAW-L18R-01, 28.92 miles, from Big Chestnut Creek to the backwaters of Leesville Lake) and Big Chestnut Creek (VAW-L15R-01, 12.88 miles, from the confluence with Little Chestnut Creek to the mouth on the Pigg River). All impaired segments are shown in Figure 2.1. Although TMDL equations will not be specifically presented for these two sections, the reductions presented in this document will affect these areas and thus a TMDL has implicitly been developed for those two stream segments.

As a point of clarification, 'Leesville Lake – Pigg River' was originally listed as part of VAW-L18R based on monitoring data from station PGG003.29. In the 2004 assessment, the segment was listed as part of VAW-L13L.

Table 2.1. Impaired Segments Addressed in this TMDL report.

Impaired Segment	Size	Target Date for TMDL Development	Description
Old Womans Creek	4.86 miles	2010	Headwaters (end of perennial section) to Old Womans Creek mouth on Roanoke River
Snow Creek	10.98 miles	2010	Snow Branch/Ditto Branch Confluence to Snow Creek mouth on Pigg River
Story Creek[1]	11.6 miles	2010	Intersection of Rt. 40 and Rt. 748 to Story Creek mouth on Pigg River
Upper Pigg River	35.06 miles	2006	South Prong Pigg River mouth on Pigg River to 10 miles downstream of the Rocky Mount STP
Leesville Lake-Pigg River	154 acres	2010	Backwaters of Leesville Lake on Pigg River to Pigg River confluence with Roanoke River

[1]DEQ Fact Sheets list this stream as 'Storey Creek', but stakeholders corrected the spelling to 'Story Creek'

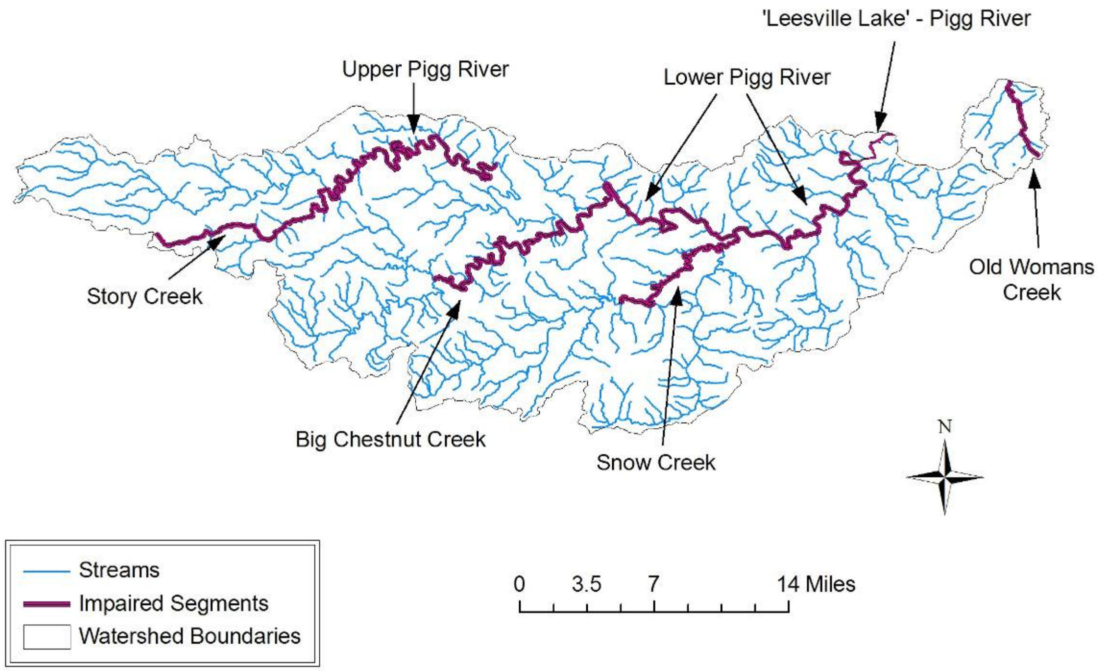

Figure 2.1. Impaired segments in the Pigg River and Old Womans Creek watersheds.

2.1.3. Watershed Location and Description

The Pigg River, Snow Creek, Story Creek, and Old Womans Creek watersheds are all part of the Roanoke River basin. The hydrologic units composing the watersheds for each stream are: Pigg River, L14-L18; Snow Creek, L17; Story Creek, part of L14; and Old Womans Creek, part of L13. Big Chestnut Creek corresponds to hydrologic unit L15. The Pigg River watershed (to which Snow Creek, Story Creek, and Big Chestnut Creek are tributaries) stretches across Franklin County and into part of Pittsylvania County, covering the northernmost point of Henry County. Old Womans Creek, adjacent to Pigg River, is located entirely inside Pittsylvania County (Figure 2.2).

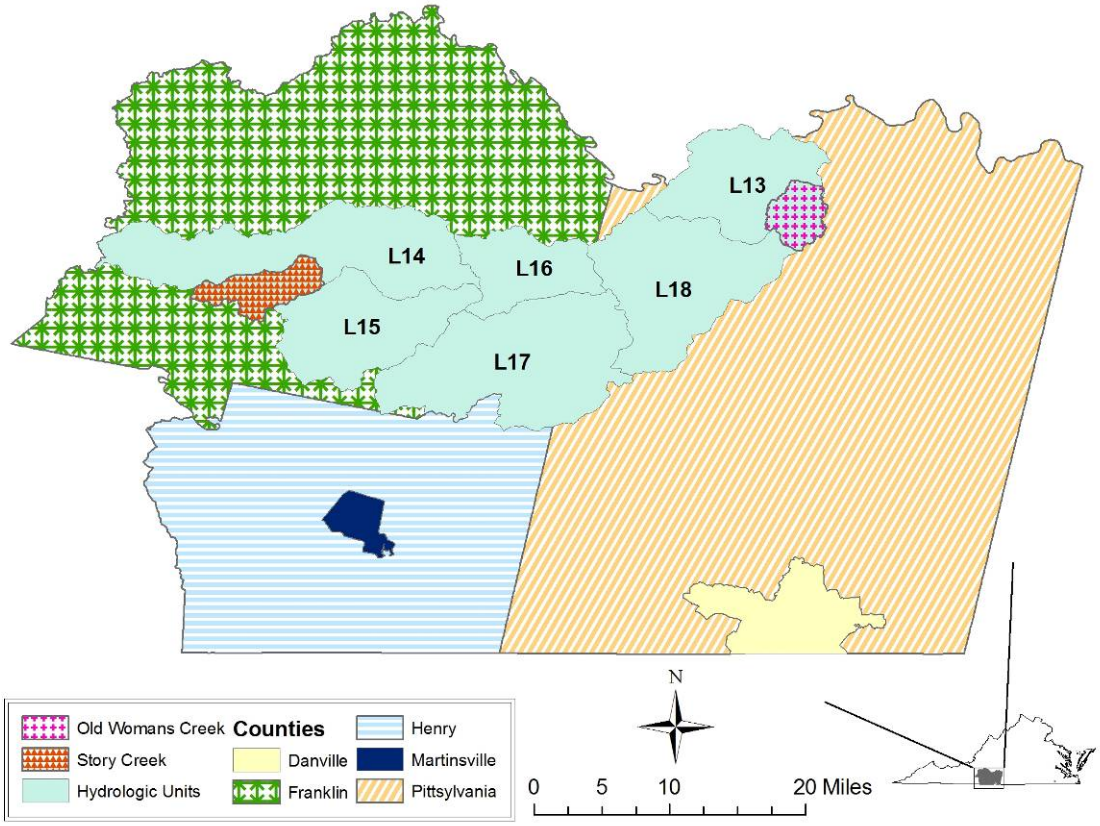

Figure 2.2. Pigg River (L14-L18), Snow Creek (L17), Story Creek (part of L14), and Old Womans Creek (part of L13) watershed locations.

The land use distribution in the four watersheds of interest are fairly similar (Table 2.2), mainly composed of forest but with a significant portion of agricultural area. Residential areas compose a small portion of all watersheds and are clustered primarily around Rocky Mount and Ferrum, both located in hydrologic unit L14. Pigg River flows east and discharges into Leesville Lake; Old Womans Creek flows north and discharges into Leesville Lake. Leesville Lake discharges to the Roanoke River (USGS Hydrologic Unit Code 03010101), which flows into the Albemarle Sound; the Albemarle Sound discharges to the Atlantic Ocean.

Table 2.2. Land use description in TMDL watersheds.

Watershed	Forest	Agriculture	Residential
Pigg River	72%	26%	2%
Snow Creek	71%	28%	1%
Story Creek	78%	20%	2%
Old Womans Creek	76%	24%	<1%

2.1.4. Pollutants of Concern

Pollution from both point and nonpoint sources can lead to fecal coliform bacteria contamination of water bodies. Fecal coliform bacteria are found in the intestinal tract of warm-blooded animals; consequently, fecal waste of warm-blooded animals contains fecal coliform. Even though most fecal coliform are not pathogenic, their presence in water indicates contamination by fecal material. Because fecal material may contain pathogenic organisms, water bodies with fecal coliform bacteria are potential sources of pathogenic organisms. For contact recreational activities such as boating and swimming, health risks increase with increasing fecal coliform counts. If the fecal coliform concentration in a water body exceeds state water quality standards, the water body is listed for violation of the state bacteria standard for contact recreational uses. As discussed in Section 2.2.2, Virginia has adopted an *Escherichia coli* (*E. coli*) water quality standard. The concentration of *E. coli* (a subset of the fecal coliform group) in water is considered to be a better indicator of pathogenic exposure than the concentration of the entire fecal coliform group in the water body.

2.2. Designated Uses and Applicable Water Quality Standards

2.2.1. Designation of Uses (9 VAC 25-260-10)

> "A. All State waters, including wetlands, are designated for the following uses: recreational uses, e.g., swimming and boating; the propagation and growth of a balanced, indigenous population of aquatic life, including game fish, which might reasonably be expected to inhabit them; wildlife; and the production of edible and marketable natural resources, e.g., fish and shellfish." SWCB, 2004.

Pigg River, Snow Creek, Story Creek, and Old Womans Creek do not support the recreational (primary contact) designated use due to violations of the bacteria criteria.

2.2.2. Bacteria Standard (9 VAC 25-260-170)

EPA has recommended that all states adopt an *E. coli* or enterococci standard for fresh water and enterococci criteria for marine waters, because there is a stronger correlation between the concentration of these organisms (*E. coli* and enterococci) and the incidence of gastrointestinal illness than there is with fecal coliform. *E. coli* and enterococci are both bacteriological organisms that can be found in the intestinal tract of warm-blooded animals and are subsets of the fecal coliform and fecal streptococcus groups, respectively. In line with this recommendation, Virginia adopted and published revised bacteria criteria on June 17, 2002. The revised criteria became effective on January 15, 2003. As of that date, the *E. coli* standard described below applies to all freshwater streams in Virginia. Additionally, prior to June 30, 2008, the interim fecal coliform standard must be applied at any sampling station that has fewer than 12 samples of *E. coli*.

For a non-shellfish water body to be in compliance with Virginia's revised bacteria standards (as published in the Virginia Register Volume 18, Issue 20) the following criteria shall apply to protect primary contact recreational uses (SWCB, 2004):

Interim Fecal Coliform Standard:

> Fecal coliform bacteria shall not exceed a geometric mean of 200 fecal coliform bacteria per 100 mL of water for two or more samples over a calendar month nor shall more than 10% of the total samples taken during any calendar month exceed 400 fecal coliform bacteria per 100 mL of water.

***Escherichia coli* Standard:**

> *E. coli* bacteria concentrations for freshwater shall not exceed a geometric mean of 126 counts per 100 mL for two or more samples taken during any calendar month and shall not exceed a single sample maximum of 235 cfu/100mL.

During any assessment period, if more than 10% of a station's samples exceed the applicable standard, the stream segment associated with that station is classified as impaired and a TMDL must be developed and implemented to bring the station into compliance with the water quality standard. There are eighteen ambient monitoring stations on Pigg River and its tributaries and two on Old Womans Creek; all but one of the Pigg River stations (in the headwaters of Snow Creek) are impaired for fecal coliform, *E. coli*, or both. The bacteria TMDL for the impaired segments will be developed to meet the *E. coli* standard. As recommended, the modeling will be conducted with fecal coliform inputs, and then a translator equation will be used to convert the output to *E. coli*.

Chapter 3: Watershed Characterization

3.1. Selection of Sub-watersheds

To account for the spatial distribution of fecal coliform sources, the Pigg River watershed was divided into 23 sub-watersheds as shown in Figure 3.1. Snow Creek was composed of sub-watershed numbers 8, 10, 11, and 12. Story Creek was composed of sub-watershed numbers 21 and 23. Upper Pigg River includes the two Story Creek sub-watersheds, as well as sub-watersheds number 19, 20, and 22. Old Womans Creek was divided into 7 sub-watersheds. The stream network used to help define the sub-watersheds was obtained from the National Hydrography Dataset. Sub-watersheds were delineated based on a number of factors: continuity of the stream network, land use, and monitoring station locations. It is preferable to have a sub-watershed outlet at or near monitoring station locations in order to calibrate the model chosen for this study (to be discussed in Chapter 5); the ten monitoring stations used in modeling are shown in Figure 3.1.

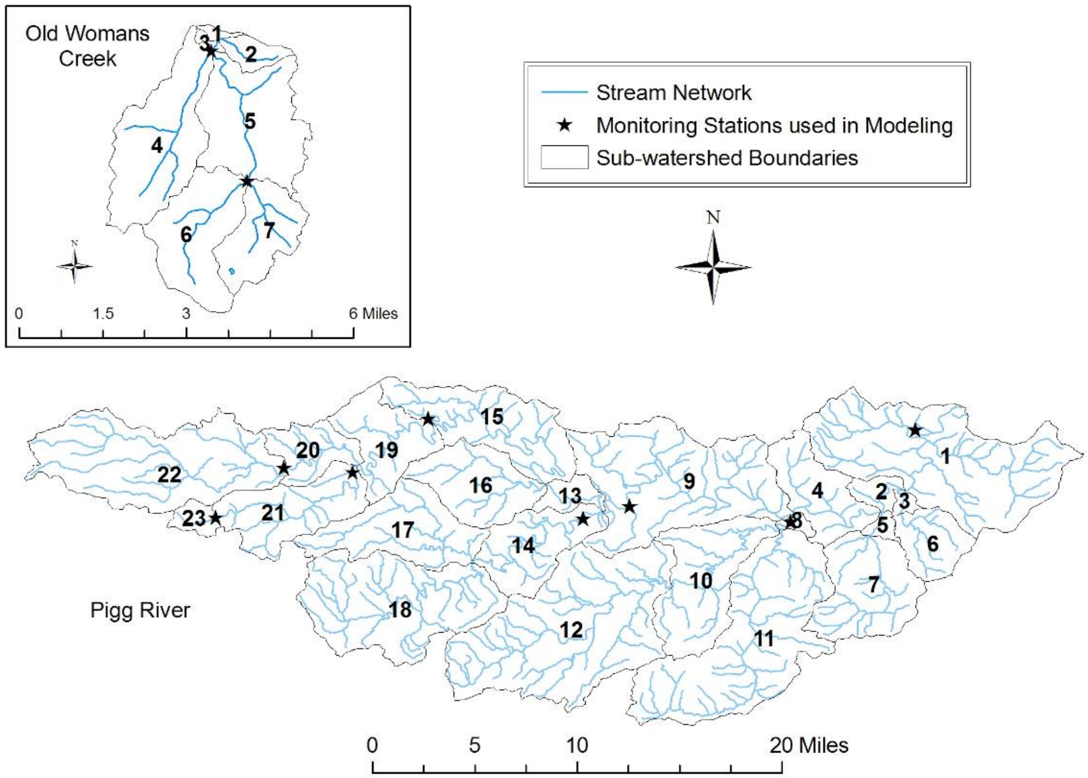

Figure 3.1. Sub-watershed boundaries for Pigg River and Old Womans Creek.

3.2. Ecoregion

The majority of the Pigg River watershed and the entire Old Womans Creek watershed are located in the Northern Inner Piedmont level IV ecoregion of the Piedmont level III ecoregion. This level IV ecoregion is composed of "hills, irregular plains, and isolated ridges and mountains" (Woods et al., 1999). Forests in this region are dominated by loblolly-short leaf pine, with some chestnut oak. Soils in the region are mainly ultisols, clayey and acidic. Roughly a third of sub-watershed 22 (in the headwaters) is located in the Blue Ridge level III ecoregion; most of this segment is in the Southern Igneous Ridges and Mountains level IV ecoregion, but a small sliver of the western tip of sub-watershed 22 is located in the Interior Plateau level IV ecoregion. The Southern Igneous Ridges and Mountains level IV ecoregion is composed of ridges and mountains, as the name suggests. Inceptisols dominate this region.

Appalachian oak forests and hardwoods dominate the vegetation. The Interior Plateau level IV ecoregion is a hilly plateau. Its soils include inceptisols, alfisols, and ultisols, and are characterized by a short depth to bedrock. Vegetation is dominated by Appalachian oak forest and oak-hickory-pine forest (Woods et al., 1999).

3.3. Soils and Geology

Five State Soil Geographic (STATSGO) soil groups are found in the Pigg River watershed. One STATSGO group is found in Old Womans Creek (Figure 3.2). The dominant STATSGO group in Pigg River, and the only one in Old Womans Creek, is Cecil-Madison-Enon, characterized by deep and well-drained soils on varying slopes with a clayey or loamy subsoil. These soils are moderately permeable. The soils are primarily formed from weathered mica gneiss and mica shist (SCS, 1994).

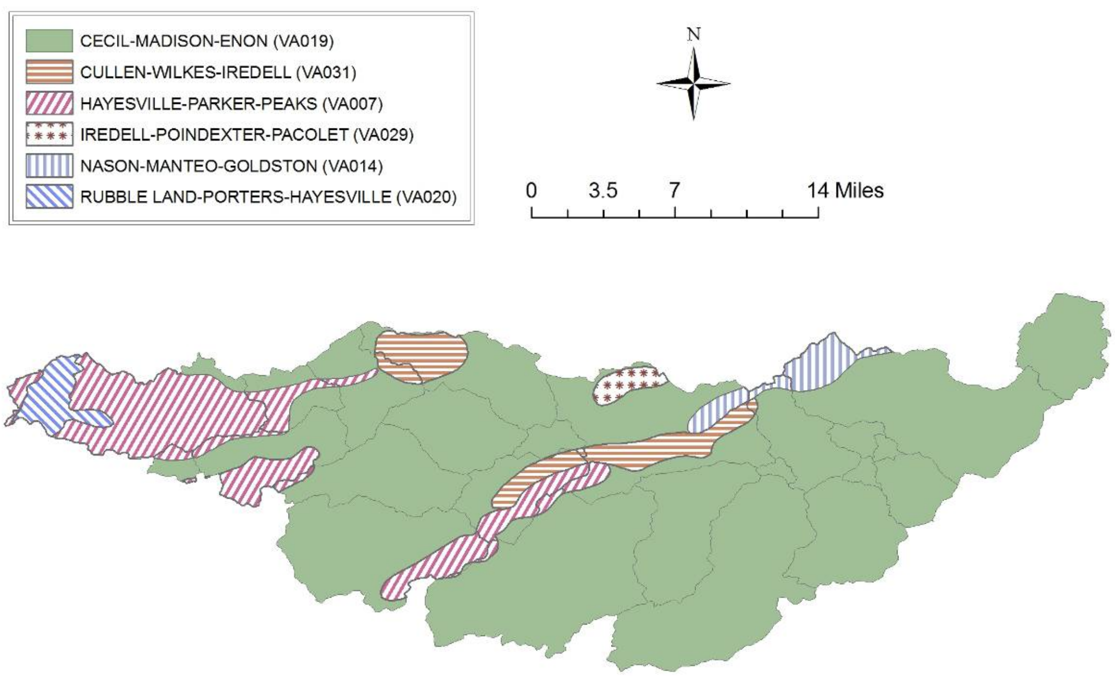

Figure 3.2. STATSGO soil groups in the Pigg River and Old Womans Creek watersheds.

3.4. Climate

The climate of the watershed was characterized based on the meteorological observations acquired at “nearby” weather stations, including Rocky Mount, Chatham, Roanoke Regional Airport, and Lynchburg Airport. Data were drawn from Rocky Mount where available; holes in the data or missing types of data were gathered from the remaining stations, in preferential order as listed above. The long-term record summary (8/1/1948-3/31/2004) at the Rocky Mount station shows an average annual precipitation of 44.65 inches, with 54% of the precipitation occurring during the cropping season (May-October). Average annual snowfall at Rocky Mount is 16.7 inches, with the highest snowfall occurring during January. Average annual daily temperature is 55.5°F. The highest average daily temperature of 75.2°F occurs in July, while the lowest average daily temperature of 35.7°F occurs in January (SERCC, 2006).

3.5. Land Use

From the 1992 National Land Cover Dataset (NLCD) (USGS, 2006), land uses in Pigg River were grouped into five major categories based on similarities in hydrologic features and waste application/production practices (Table 3.1). The five land use categories were assigned pervious and impervious percentages for use in the watershed model. Land uses for the Pigg River and Old Womans Creek watersheds are presented graphically in Figure 3.3. Land uses are tabulated for the watersheds in Table 3.2 for Pigg River and tributaries and Table 3.3 for Old Womans Creek.

Table 3.1. NLCD aggregation.

TMDL Land Use Categories	Pervious/Impervious (Percentage)	NLCD Land Use Categories (Class No.)
Cropland	Pervious (100%)	Row Crops (82)
Pasture	Pervious (100%)	Pasture/Hay (81)
Low Density Residential (LDR)	Pervious (70%) Impervious (30%)	Low Intensity Residential (21) Transitional (33) Urban/Recreational Grasses (85)
High Density Residential (HDR)	Pervious (20%) Impervious (80%)	High Intensity Residential (22) Commercial/Industrial/Transport (23) Quarries/strip mines/gravel pits (32)
Forest	Pervious (100%)	Open Water (11) Deciduous Forest (41) Evergreen Forest (42) Mixed Forest (43) Woody Wetlands (91) Emergent Herbaceous Wetlands (92)

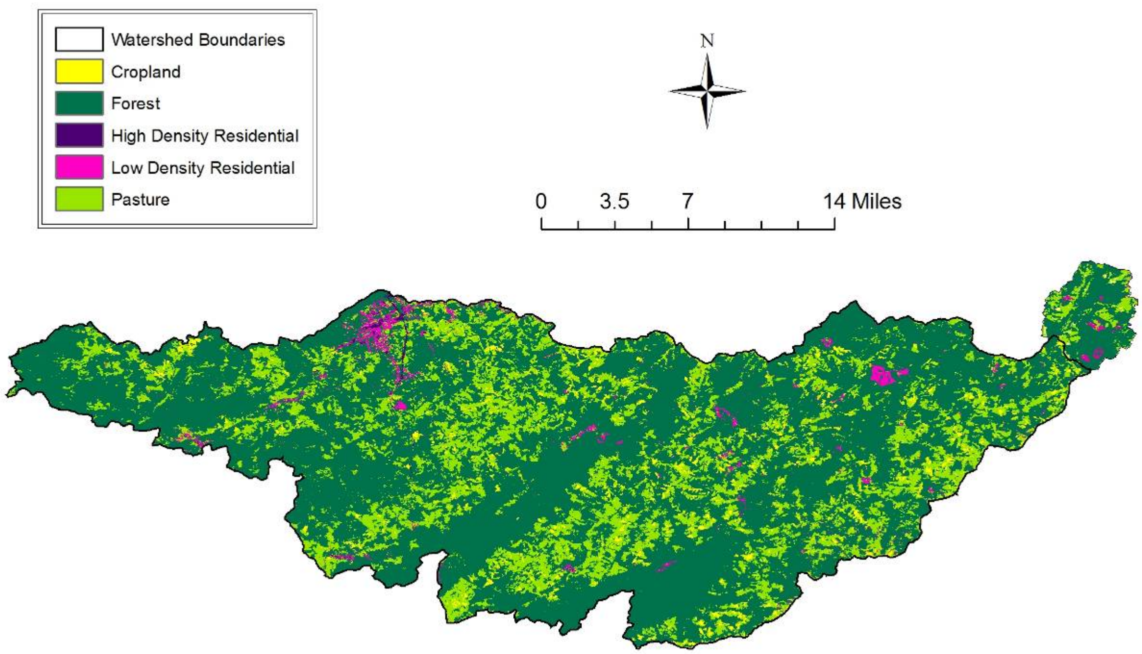

Figure 3.3. Land use in Pigg River and Old Womans Creek.

Table 3.2. Land use areas in Pigg River (acres).

Sub-watershed	Cropland	Forest	HDR*	LDR†	Pasture
1	974.15	20,102.58		599.69	4,618.92
2	26.32	1,440.73		5.33	188.61
3	36.69	420.21		9.84	142.45
4	319.78	5,986.59		86.91	1,189.11
5	19.86	613.68		0.81	151.50
6	343.51	2,442.79		47.34	2,104.03
7	507.95	7,055.84	0.32	160.94	3,229.59
8‡	30.26	394.54		0.32	183.36
9	706.62	17,734.40	0.73	235.86	4,590.13
10‡	598.27	8,225.35	1.33	151.90	3,125.11
11‡	941.51	18,926.72	6.16	120.92	4,448.27
12‡	1,018.46	19,353.88	12.91	100.22	8,393.01
13	68.60	1,449.06		2.00	598.49
14	141.41	7,079.39		133.55	1,158.46
15	386.66	7,280.12	215.51	659.06	3,975.93
16	330.46	5,047.79	11.91	60.27	3,583.38
17	212.72	8,238.66	29.77	109.07	2,648.43
18	324.30	14,806.93	38.05	105.97	4,176.34
19	55.63	5,416.13	235.36	830.22	1,457.44
20	125.39	3,088.11	15.08	88.73	1,552.78
21‡	184.48	7,649.24	0.29	84.78	1,872.58
22	421.42	18,089.30	0.44	34.94	3,175.97
23‡	9.71	1,119.62	10.76	124.41	245.23
Total	7,784.16	181,961.66	578.62	3,753.10	56,809.12

*High Density Residential
†Low Density Residential
‡Sub-watersheds 8, 10-12 comprise Snow Creek; Sub-watersheds 21 and 23 comprise Story Creek

Table 3.3. Land use areas in Old Womans Creek (acres).

Sub-watershed	Cropland	Forest	LDR*	Pasture
1	72.58	1,623.86	35.88	555.35
2	98.87	1,620.83	45.71	674.54
3	2.91	1,021.30	82.30	130.33
4	42.82	1,403.76	127.81	291.56
5	0.31	52.10	0.00	15.96
6	1.56	53.79	0.00	8.82
7	12.97	242.15	1.99	70.66
Total	232.02	6,017.79	293.69	1,747.22

*Low Density Residential

3.6. Stream Flow Data

USGS monitors average daily flow rates on Pigg River at station 02058400, Pigg River near Sandy Level, VA, at the outlet of sub-watersheds 2 and 3 (Figure 2). This station drains 350 mi² of the Pigg River basin. The station record extends from June 1963 to the present. The average flow rate at this station since 1980 is 382 cfs. A second station on Pigg River, 02058500, Pigg River near Toshes, VA, includes more of the watershed (394 mi²), but only collected data from 1930 to 1963. Thus, a hydrologic calibration and validation for Pigg River was performed using data from station 02058400. Snow Creek and Story Creek contributed to this station, and thus the parameters describing these two watersheds were included in the calibration. No flow gage was available at the outlet of Old Womans Creek, and thus calibrated hydrologic parameters from Pigg River were used in the Old Womans Creek model.

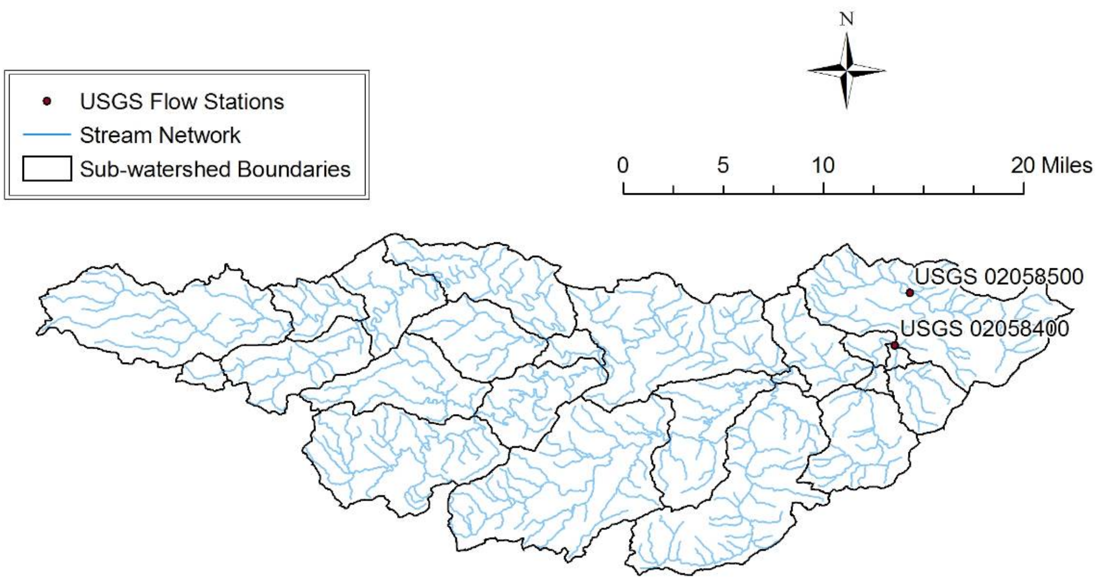

Figure 3.4. USGS flow monitoring stations on Pigg River.

3.7. Water Quality Data

The Virginia Department of Environmental Quality (VADEQ) monitored Pigg River water quality at numerous stations with varying periods of record (Table 3.4). Water quality data were recorded for at least one station on Pigg River from 1990 to present; at least one station on Snow Creek from 1988 to present; at least one station on Story Creek from 1988 to present; and at least one station on Old Womans Creek from 1992 to present. The locations of the monitoring stations are shown in Figure 3.5. Details on the data for each station are given in Table 3.5. Of the stations in Pigg River and Old Womans Creek, one (4APGG052.73) is a trend station designed to record long-term trends in water quality. Ten of the stations in Table 3.4 were chosen for use in water quality calibration; these particular stations are shown in Figure 3.1; the corresponding watershed outlets for these stations are given in Table 3.6.

Table 3.4. VADEQ monitoring stations in Pigg River and Old Womans Creek.

Watershed Code	Station ID	Station Description	Stream Name	County
VAW-L13R	4AOWC002.35	Paisley Rd. (Rt. 756)	Old Womans Creek	Pittsylvania
VAW-L13R	4AOWC005.36	STA #17 Rt. 760 Bridge	Old Womans Creek	Pittsylvania
VAW-L14R	4ADOE002.47	Rt. 720 Bridge	Doe Run	Franklin
VAW-L14R	4APGG052.73	Rt. 713 Bridge Upstream of Rocky Mount STP	Pigg River	Franklin
VAW-L14R	4APGG068.49	Rt. 756 Bridge	Pigg River	Franklin
VAW-L14R	4APGG074.87	STA #18 Rt. 908 Ford	Pigg River	Franklin
VAW-L14R	4ASDA007.24	Rt. 40 Bridge Near Ferrum	Story Creek	Franklin
VAW-L14R	4ASDA009.77	Off Rt. 864, Below Ferrum STP Outfall	Story Creek	Franklin
VAW-L14R	4ASDA009.79	Rt. 623 Bridge Above Ferrum STP Outfall	Story Creek	Franklin
VAW-L14R	4ASDA000.67	Davis Mill Bridge	Story Creek	Franklin
VAW-L15R	4ACNT001.32	Rt. 715 Bridge	Big Chestnut Creek	Franklin
VAW-L16R	4APGG030.62	Rt. 646 Bridge	Pigg River	Franklin
VAW-L17R	4ASNW000.60	Kirby Ford Bridge	Snow Creek	Pittsylvania
VAW-L17R	4ASNW010.08	Rt. 651	Snow Creek	Franklin
VAW-L18R	4AHPN001.62	Rt. 785 Bridge	Harpen Creek	Pittsylvania
VAW-L18R	4APGG003.29	Rt. 605 Bridge	Pigg River	Pittsylvania
VAW-L18R	4APGG008.42	Rt. 40 Bridge, Near Gaging Station	Pigg River	Pittsylvania
VAW-L18R	4APGG008.87	Off Rt. 40 at USGS Gage	Pigg River	Pittsylvania
VAW-L18R	4APGG016.06	Rt. 626 Bridge	Pigg River	Pittsylvania
VAW-L18R	4ATMA001.46	Rt. 644 Bridge	Tomahawk Creek	Pittsylvania

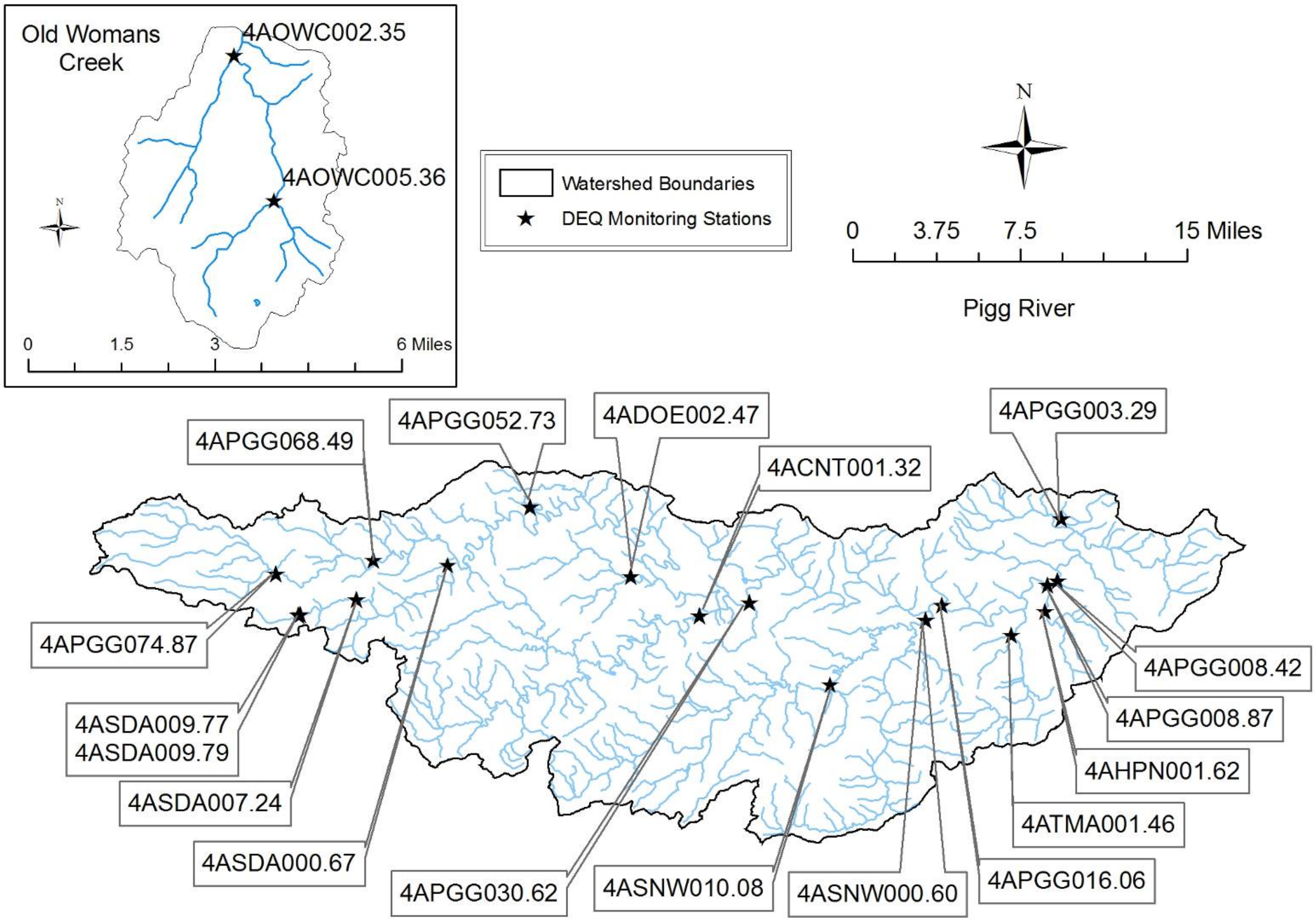

Figure 3.5. Monitoring station locations in Pigg River and Old Womans Creek.

Table 3.5. Details of data collected at monitoring stations in Pigg River and Old Womans Creek.

Station ID	Sample Date[*]		No. of Samples	Sample Value (cfu/100 mL)			Exceedances of Single Sample Standard	
	First	Last		Min	Max	Avg	No.	%
4AOWC002.35	7/20/2004	4/27/2005	9	10	6,900	882	2	22%
4AOWC005.36	8/11/1992	4/27/2005	45	20	8,000[†]	740	13	29%
4ADOE002.47	7/11/2001	5/27/2003	45	100[†]	2,100	392	3	25%
4APGG052.73	3/22/1994	4/27/2005	123	40	16,000[†]	1,241	50	41%
4APGG068.49	7/26/2001	4/27/2005	21	75	8,000[†]	851	6	29%
4APGG074.87	7/26/2001	4/21/2005	22	100[†]	8,000[†]	1,262	8	36%
4ASDA007.24	9/24/2001	4/21/2005	16	50	4,700	464	2	13%
4ASDA009.77	7/11/1988	6/19/2001	144	100[†]	8,000[†]	1,366	59	41%
4ASDA009.79	7/1/1988	4/21/2005	121	20	8,000[†]	1,273	66	54%
4ASDA000.67	7/20/2004	4/27/2005	9	100	7,000	1,123	4	44%
4ACNT001.32	1/13/1997	5/7/2001[‡]	21	100[†]	2,300	257	2	10%
4APGG030.62	7/26/1994	4/27/2005	50	50	8,000[†]	710	13	26%
4ASNW000.60	12/12/1988	4/27/2005	66	10[†]	9,200	974	18	27%
4ASNW010.08	8/31/2004	4/27/2005	5	25	350	167	0	0%
4AHPN001.62	8/11/2003	4/27/2005	11	25	16,000	2,414	9	82%
4APGG003.29	3/19/1990	4/27/2005	70	25	9,200	1,017	25	36%
4APGG008.42	1/19/1988	3/13/1989	8	100[†]	500	175	1	13%
4APGG008.87	8/11/2003	4/27/2005	11	25	9,200	1,659	5	45%
4APGG016.06	8/11/2003	4/27/2005	11	25[†]	16,000	2,292	5	45%
4ATMA001.46	8/11/2003	4/27/2005	11	25[†]	5,200	789	3	27%

[*]As of May 2005
[†]Capped value
[‡]Only *E. coli* samples were collected after this date

Table 3.6. Monitoring stations used in modeling for Pigg River and Old Womans Creek.

Station ID	Stream	Located at Outlet of Sub-watershed[1]
4ASDA000.67	Story Creek	21
4ASDA009.79[2]	Story Creek	23
4ASNW000.60[2]	Snow Creek	8
4ACNT001.32	Big Chestnut Creek	14
4APGG003.29[2]	Pigg River	1
4APGG030.62[2]	Pigg River	13 & 14
4APGG052.73[2]	Pigg River	19
4APGG068.49	Pigg River	22
4AOWC002.35	Old Womans Creek	4 & 5
4AOWC005.36[2]	Old Womans Creek	6 & 7

[1]See Figure 3.1 for sub-watershed numbers
[2]Station caused impairment listing for stream

As part of the TMDL effort, bacterial source tracking (BST) data were collected at seven of the stations shown in Table 3.4 and Figure 3.5: 4ASDA000.67, 4ASNW000.60, 4APGG003.29, 4APGG030.62, 4APGG052.73, 4APGG068.49, and 4AOWC002.35. The commonly used Antibiotic Resistance Analysis (ARA) method was used to analyze these samples (Harwood et al., 2003; Stoeckel, et al., 2004; Hagedorn, 2006). This method is lower in cost and faster than many of the other available methods. The ARA method is classified as a biochemical or phenotype analysis. It relies on the response of the fecal bacteria to various antibiotics. The results of the BST analyses are presented at the end of Chapter 5, where they are compared with modeled results.

The assessments for Leesville Lake-Pigg River and Old Womans Creek show a potential for bacteria contributions from agriculture and wildlife; for Upper Pigg River, agriculture, urban, and wildlife; for Story Creek, agriculture and urban; and for Snow Creek, agriculture. The exceedance rates for the stations causing the impairment listings on these watersheds are given in Table 3.7. As a consequence of these exceedances, Old Womans Creek, Story Creek, Snow Creek, and three segments of Pigg River were assessed as not supporting the Clean Water Act's Primary Contact Recreational Use Goal for the 2004 305(b) report and were included on the 2004 303(d) list (VADEQ, 2004). The bacteria concentrations for each of the stations in Table 3.7 are shown in Figure 3.6-Figure 3.11, along with the 2004 assessment period, interim fecal coliform standard, and caps on the data.

Table 3.7. Bacteria standard exceedances during the 2004 assessment period (1998-2002).

Station ID	Exceedances of Interim Fecal Coliform Standard
4ASDA009.79	13 of 24 (54%)
4ASNW000.60	3 of 17 (18%)
4APGG003.29	4 of 18 (22%)
4APGG030.62	7 of 27 (26%)
4APGG052.73	15 of 57 (26%)
4AOWC005.36	3 of 17 (18%)

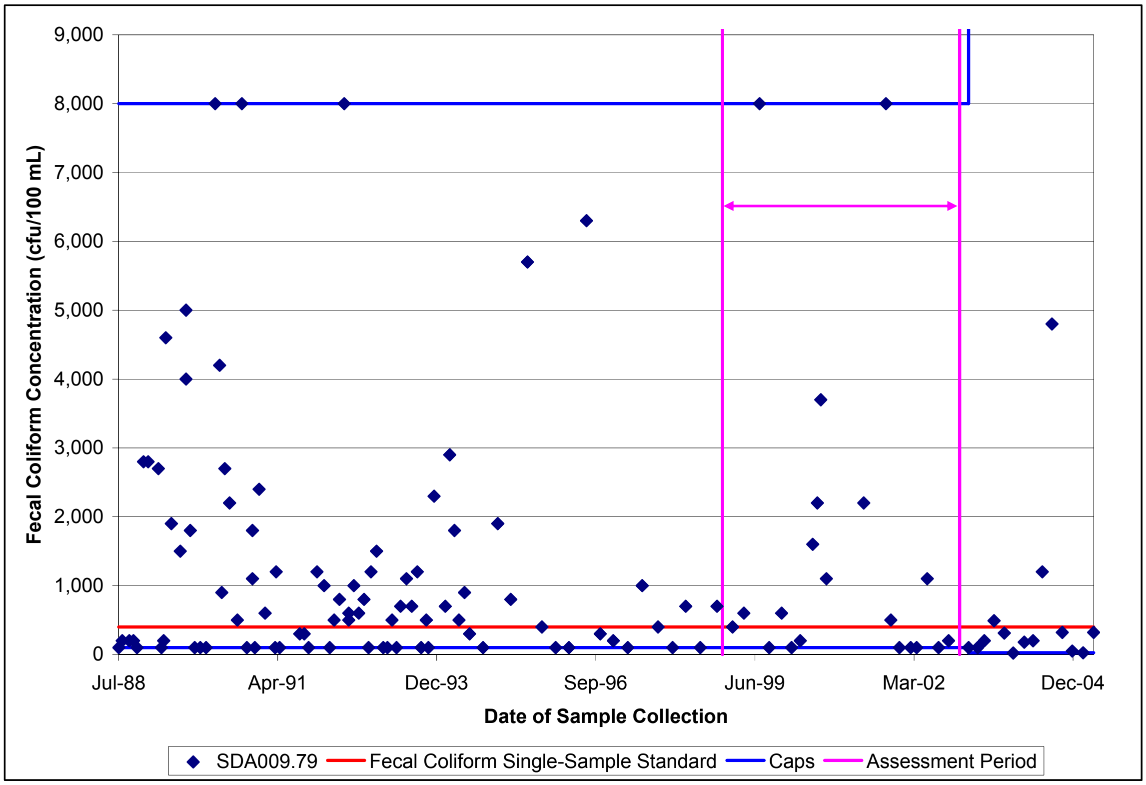

Figure 3.6. Bacteria data for Station 4ASDA009.79.

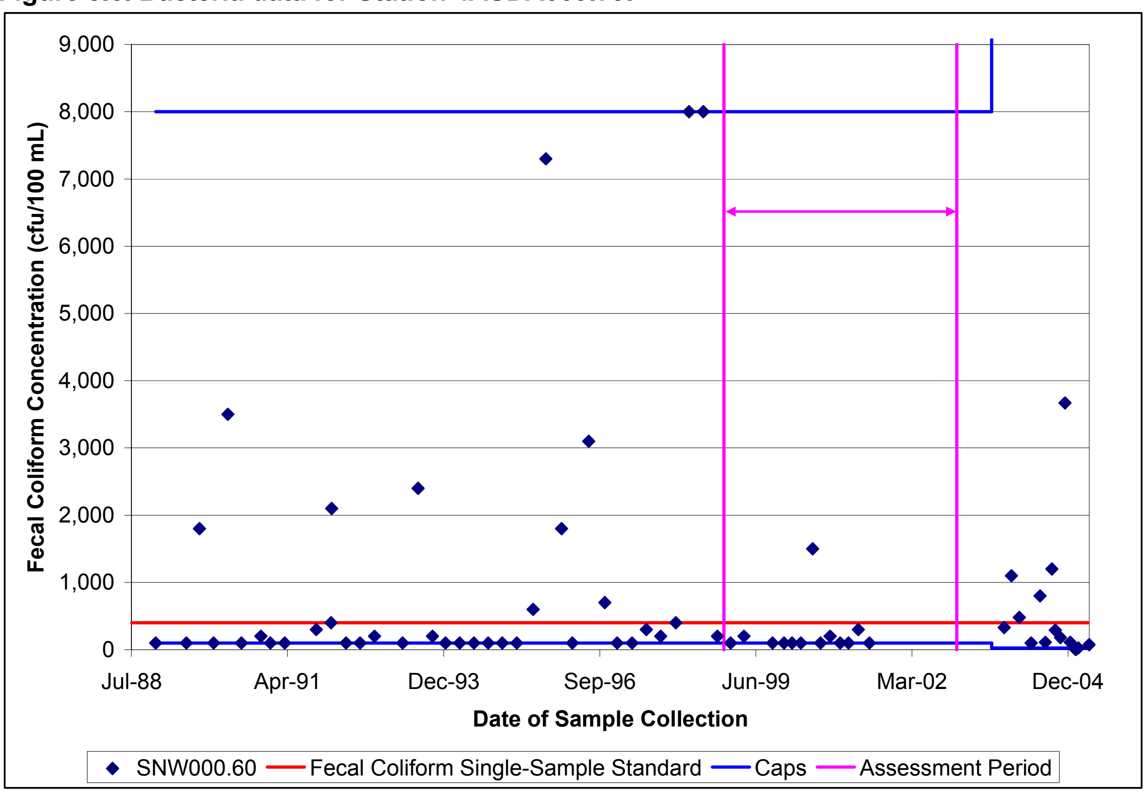

Figure 3.7. Bacteria data for Station 4ASNW000.60.

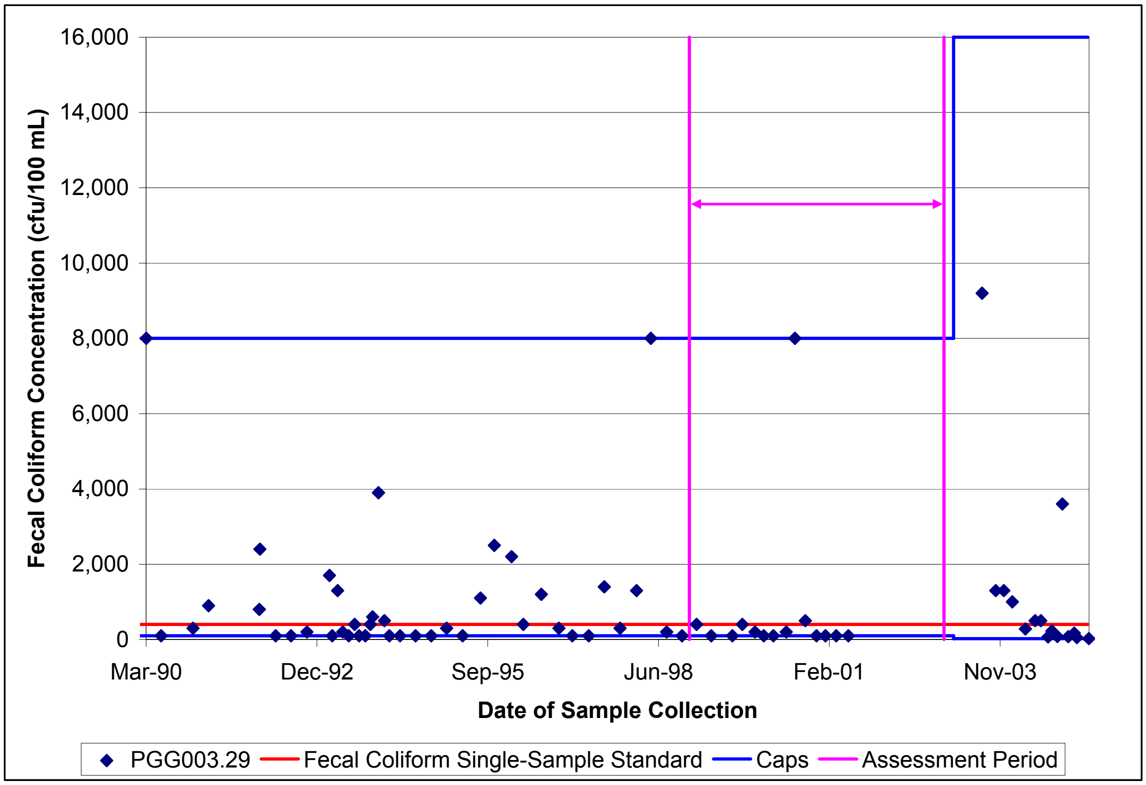

Figure 3.8. Bacteria data for Station 4APGG003.29.

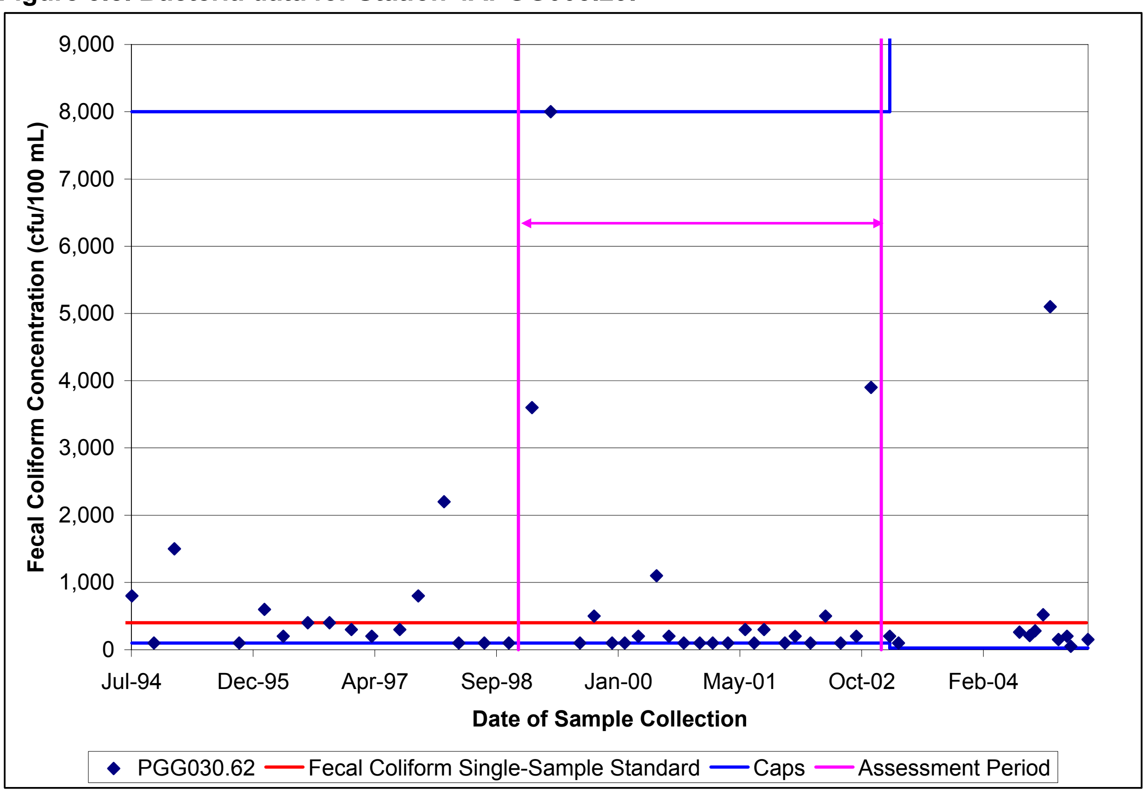

Figure 3.9. Bacteria data for Station 4APGG030.62.

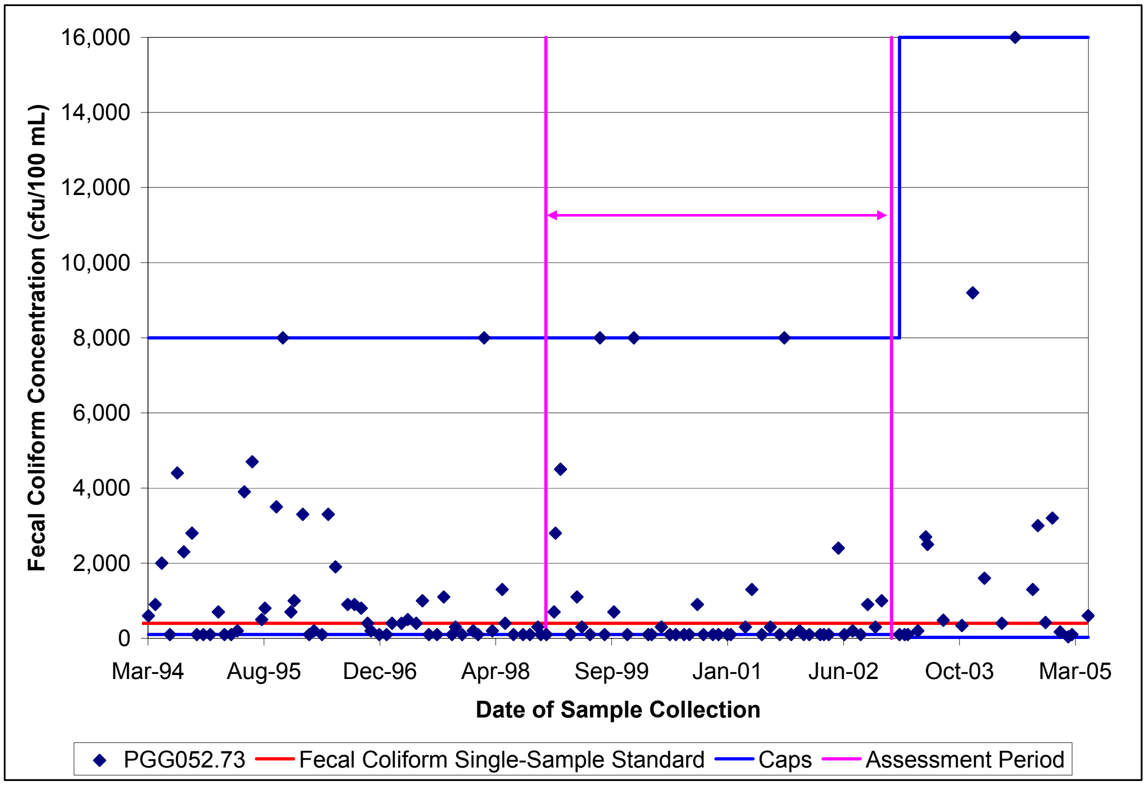

Figure 3.10. Bacteria data for Station 4APGG052.73.

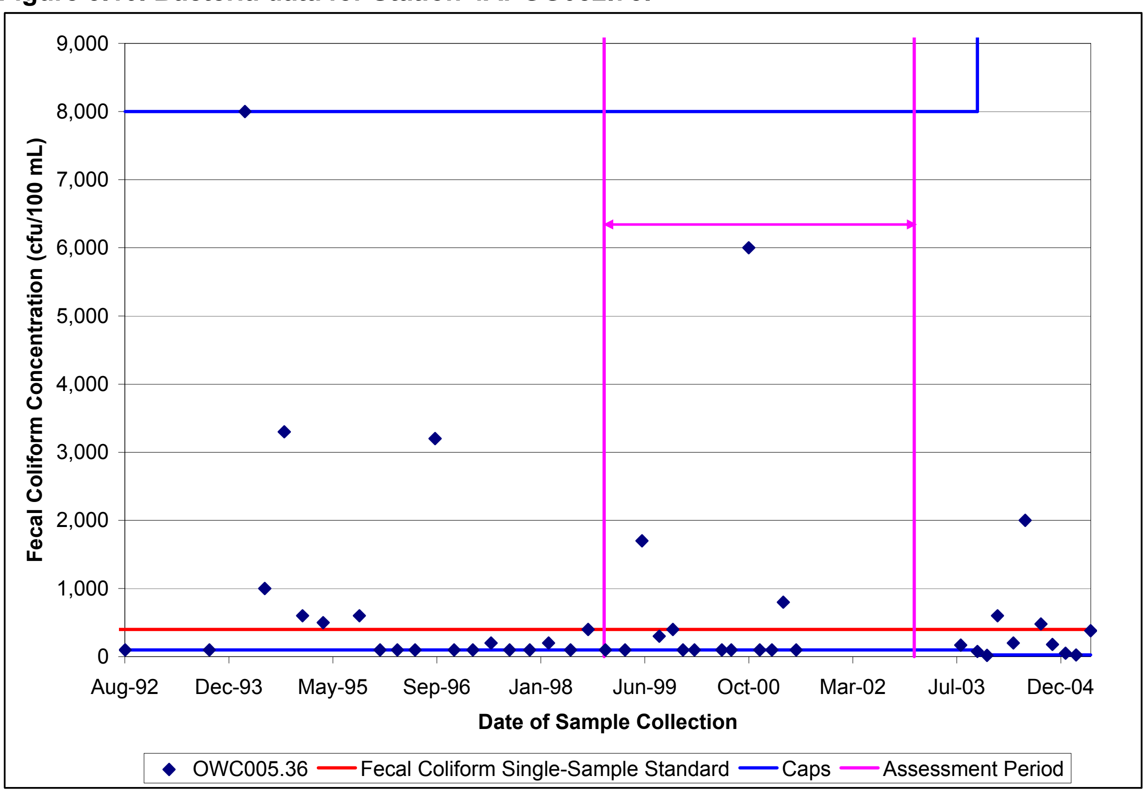

Figure 3.11. Bacteria data for Station 4AOWC005.36.

Until 2003, the Membrane Filter Method (MFM) was used for the analysis of the bacteria samples presented in the previous figures. After 2003, the Most Probable Number (MPN) method was used to analyze the bacteria samples. The former method imposed a cap of 8,000 cfu/100 mL as a maximum; the latter a cap of 16,000 cfu/100 mL. The MFM imposed a lower cap of 100 cfu/100 mL; after 2003, a lower cap of 25 cfu/100 mL was imposed.

Seasonality of fecal coliform concentrations in the streams was evaluated by plotting the mean monthly fecal coliform concentrations observed at the listing stations (Figure 3.12). Mean monthly fecal coliform concentration was determined as the mean of 1 to 18 values per month where data were available (some stations, as 4AOWC005.36, did not have any values collected in certain months); the number of values varied according to the available number of samples for each month in the period of record. The most data points available per month were for stations 4APGG052.73 and 4ASDA009.79; the least were available for 4AOWC005.36.

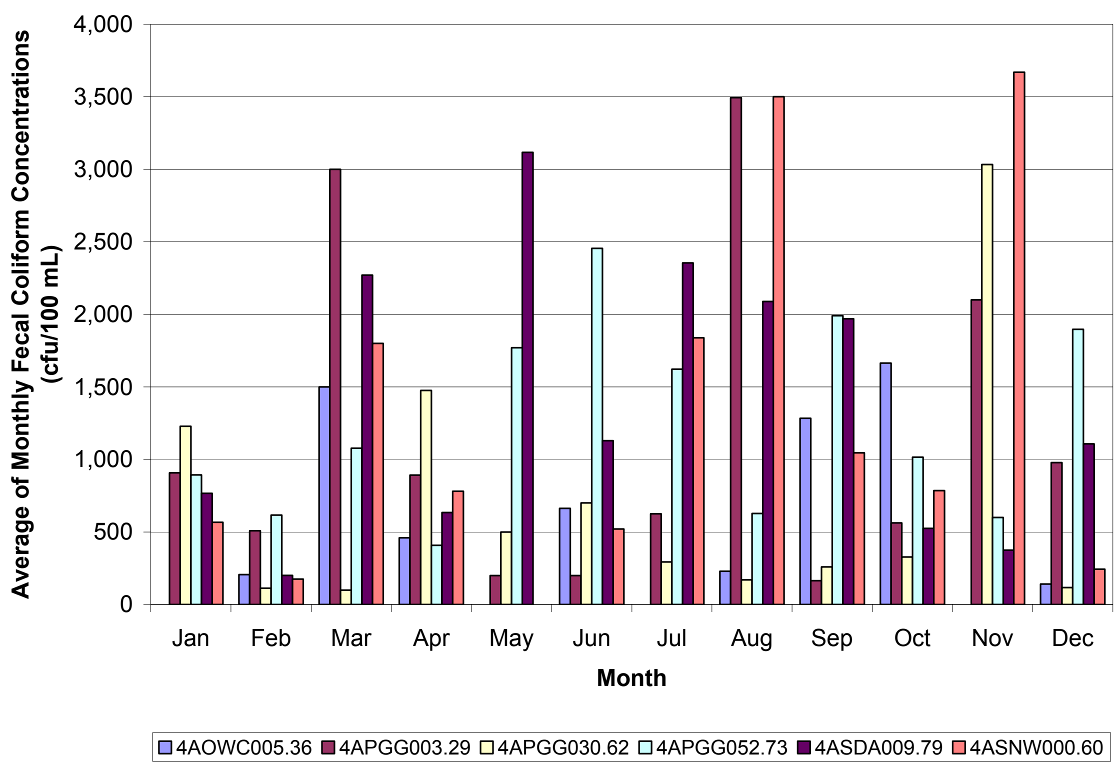

Figure 3.12. Average fecal coliform concentrations by month for the six listing stations.

The data show a clear variability by month, but in general lack strong seasonal trends. Station 4APGG0052.73 shows the strongest seasonal trends, with higher values in May, June, and July. In general, contributions in the winter months (December, January, February) appear lower than the rest of the year, but this is not always the case. The lack of strong seasonality suggests that the sources of bacteria to the impaired watersheds are less affected by seasonal trends (precipitation, management practices, and migration patterns).

Chapter 4: Source Assessment of Fecal Coliform

Fecal coliform sources in the Pigg River watershed were assessed using information from the following sources: VADEQ, VADCR, Virginia Department of Game and Inland Fisheries (VADGIF), Virginia Department of Agricultural and Consumer Services (VDACS), Virginia Cooperative Extension (VCE), Natural Resources Conservation Service (NRCS), Soil and Water Conservation Districts (SWCD), public participation, watershed reconnaissance and monitoring, published information, and professional judgment. Point sources and potential nonpoint sources of fecal coliform are described in detail in the following sections and summarized in Table 4.1 and Table 4.2. In an effort to adequately represent the historic condition of the watershed, changes to some populations were made for four periods: calibration (1994-1998), validation (1999-2005), existing conditions, and future conditions. If a particular population was affected by the different time periods, it is noted in the text in the appropriate section.

Point sources of fecal coliform bacteria in the Pigg River watershed include three wastewater treatment plants – two currently in operation and one scheduled to go online in the near future. One of the currently operational facilities (Ferrum Town – STP) is located in the Story Creek watershed. Virginia issues Virginia Pollutant Discharge Elimination System (VPDES) permits for point sources of pollution. In Virginia, point sources that treat human waste are required to maintain an *E.coli* concentration of 126 cfu/100 mL or less in their effluent. In allocation scenarios for bacteria, the entire allowable point source discharge concentration of 126 cfu/100 mL was used. Additionally, two companies hold permits to apply Class B municipal biosolids in the Pigg River watershed. No permitted sources existed in the Old Womans Creek watershed.

Table 4.1. Potential fecal coliform sources and daily fecal coliform production by source for existing conditions in the Pigg River and Old Womans Creek watersheds.

Potential Source	Population in Pigg River	Population in Old Womans Creek	Fecal coliform produced (x 10^6 cfu/head/day)
Humans	22,129	487	2,000[a]
Dairy Cattle			
Milk and dry cows	4,831	0	18,950[b]
Heifers[c]	2,497	0	8,663[d]
Beef Cattle	5,970	248	9,600[b]
Pets	9,094	194	450[e]
Poultry - Pullets	17,000	0	28[f]
Llamas	50	0	28,000[g]
Horses	292	19	420[h]
Deer	11,793	390	350
Raccoons	8,665	272	50
Muskrats	1,262	28	25[i]
Beavers	1,378	20	0.2
Wild Turkeys	3,095	75	93
Ducks[j]	4,392; 2,927	115; 78	2,400
Geese[j]	5,123; 3,658	136; 97	800

[a] Source: Geldreich (1978)
[b] Based on data presented by Metcalf and Eddy (1979) and ASAE (1998)
[c] Includes calves
[d] Based on weight ratio of heifer to milk cow weights and fecal coliform produced by milk cow
[e] Source: Weiskel *et al*. (1996)
[f] Based on bacteria concentration in chicken manure (ASAE(1998)) and relative manure production by pullets and chickens
[g] Based on bacteria production by sheep (ASAE(1998)) and relative weights of sheep and goats (ASAE(1998)): goats and llamas were assumed to have similar fecal coliform production rates
[h] Source: ASAE(1998)
[i] Source: Yagow (2001)
[j] Population given as winter; summer population

Table 4.2. Permitted facilities discharging into the streams of the Pigg River watershed.

Permit Number	Facility Name	Sub-watershed	Design Flow (mgd[*])	Permitted *E. coli* Conc. (cfu/100 mL)	*E. coli* Load (cfu/year)
VA0029254	Ferrum Town – STP	21	0.4	126	6.99×10^{12}
VA0091103[†]	Franklin County Commerce Center WWTP	17	0.02	126	3.48×10^{10}
VA0085952	Rocky Mount Town STP	15	2	126	3.48×10^{12}

[*]million gallons per day
[†]Not currently online

4.1. Humans and Pets

The Pigg River watershed has an estimated population of 22,129 people (9,094 households at an average of 2.43 people per household; actual people per household varies by sub-watershed). The Old Womans Creek watershed has an estimated population of 487 people (194 households with at an average of 2.51 people per household). The number of people per household for both watersheds was determined from the 2000 Census. Fecal coliform from humans can be transported to streams from failing septic systems, via straight pipes discharging directly into streams, and through leaky sewer lines. Although leaky sewer lines were not explicitly accounted for in modeling for this TMDL, they are considered to be part of the residential load, and should be addressed where found during implementation.

4.1.1. Failing Septic Systems

Septic system failure can be evidenced by the rise of effluent to the soil surface. Surface runoff can transport the effluent, containing fecal coliform, to receiving waters. In order to estimate the number of failing septic systems, it is necessary to determine both the number and age of houses in the watersheds. Households in Pittsylvania and Henry Counties were located according to electronic data available from the GIS departments of the respective counties; Franklin County did not have these data available. In Franklin County, houses were located according to the structure locations on United States Geologic Survey (USGS) 7.5-min quadrangle topographic maps. For all counties, house ages were determined from the USGS quadrangles. Structures on USGS quadrangles are shown in black for the first publication of the maps in the 1960s and purple for the revision of the maps in the 1980s. Comparison of the locations of houses in current electronic data to the locations of structures on the USGS quadrangles thus allows the classification of houses into three age categories: ‘old’ houses (built ~pre-1965) and ‘mid-age’ houses (built ~1965-1985), and ‘new’ houses (built ~post-1985, do not appear on USGS maps). To obtain ‘new’ houses for Franklin County, the total number of houses from the

USGS maps was subtracted from the number of households from the 2000 Census area-weighted block groups. It was estimated that 1,636 households in Pigg River were connected to the sewer line (in sub-watersheds 15 and 19). For houses not connected to the sewer line, it was assumed that septic system failure rates for houses in the old, mid-age, and new categories were 40, 20, and 3%, respectively (R.B. Reneau, personal communication, 3 December 1999, Blacksburg, Va.). Estimates of these failure rates were also supported by the Holmans Creek Watershed Study (a watershed located in Rockingham County), which found that over 30% of all septic systems checked in the watershed were either failing or not functioning at all (SAIC, 2001).

Daily total fecal coliform load to the land from a failing septic system in a particular sub-watershed was determined by multiplying the average occupancy rate for that sub-watershed (occupancy rate of houses not on a sewer line ranged from 2.38 to 2.61 persons per household for Pigg River and was a constant 2.51 persons per household for Old Womans Creek (Census Bureau, 2000)) by the per capita fecal coliform production rate of 2.0×10^9 cfu/day (Geldreich, 1978). Hence, the total fecal coliform loading to the land from a single failing septic system in a sub-watershed with an occupancy rate of 1 person/household was 2.0×10^9 cfu/day. Transport of some portion of the fecal coliform to a stream by runoff may occur. The number of failing septic systems in the watersheds is given in Table 4.3 for Pigg River and Table 4.4 for Old Womans Creek.

4.1.2. Straight Pipes

Of the houses located within 150 ft of streams in the old and mid-age categories, 10% and 2%, respectively, were estimated to have straight pipes (R.B. Reneau, personal communication, 3 December 1999, Blacksburg, Va.). Based on these criteria, it was estimated that 14 houses with straight pipes exist in the Pigg River watershed, and none exist in the Old Womans Creek watershed. Bacteria discharged from straight pipes enter the stream directly, without treatment or die-off. The number of straight pipes in the Pigg River watershed is given in Table 4.3 for Pigg River and Table 4.4 for Old Womans Creek.

Table 4.3. Estimated Household and Pet Population Breakdown by Sub-watershed for Pigg River.

Sub-watershed	Sewered Houses	People per House (un-sewered)	Unsewered houses in each age category				Failing Septic Systems	Pet Population
			Straight Pipes	Old	Mid-age	New		
1	0	2.46	0	241	86	137	118	582
2	0	2.57	0	7	5	6	4	22
3	0	2.61	0	6	3	5	3	17
4	0	2.51	0	59	16	19	27	121
5	0	2.61	0	5	0	0	2	7
6	0	2.6	0	47	17	12	23	99
7	0	2.38	0	116	33	33	54	236
8*	0	2.38	0	5	0	3	2	10
9	0	2.51	0	250	11	134	106	501
10*	0	2.46	1	159	32	19	71	282
11*	0	2.48	1	244	79	107	117	548
12*	0	2.43	1	317	130	108	156	712
13	0	2.54	0	33	32	3	20	88
14	0	2.5	0	87	110	5	57	259
15	185	2.44	2	375	196	296	198	1,252
16	0	2.57	0	250	202	2	140	594
17	0	2.52	0	154	233	0	108	495
18	0	2.46	2	274	218	107	156	757
19	1,451	2.42	3	314	262	118	182	2,330
20	0	2.55	1	212	291	30	144	678
21†	0	2.52	1	246	353	6	169	775
22	0	2.56	1	214	101	89	108	513
23†	0	2.47	1	180	0	0	72	253
Total	1,636	2.43	14	3,795	2,410	1,239	2,037	11,131

*Snow Creek sub-watersheds
†Story Creek sub-watersheds

4.1.3. Pets

Assuming one pet per household, there are 9,094 pets in the Pigg River watershed and 194 pets in the Old Womans Creek watershed. A dog produces fecal coliform at a rate of 0.45 x 10^9 cfu/day (Weiskel et al., 1996); this was assumed to be representative of a 'unit pet' – one dog or several cats. The pet population distribution among the sub-watersheds is listed in Table 4.3 for Pigg River and Table 4.4 for Old Womans Creek. Pet waste is generated in residential areas; surface runoff can transport bacteria in pet waste from these areas to the stream.

Table 4.4. Estimated Human and Pet Population Breakdown by Sub-watershed for Old Womans Creek.

Sub-watershed	Unsewered houses in each age category			Failing Septic Systems	Pet Population
	Old	Mid-age	New		
1	2	0	0	1	2
2	8	6	12	5	26
3	0	1	0	0	1
4	23	6	42	12	71
5	19	17	29	12	65
6	2	8	9	3	19
7	3	3	4	2	10
Total	57	41	96	35	194

4.1.4. Future Conditions

The human and pet populations were held constant throughout the calibration, validation, and existing conditions. However, to account for future growth in the Pigg River watershed, sections of the comprehensive plan currently under development for Franklin County were used to estimate new numbers for future conditions. A comprehensive plan was not available for Pittsylvania County. The comprehensive plan provides a preliminary estimate of a 24% increase in population between 2000 and 2020. The plan also showed a historical change in population by magisterial district. The Rocky Mount district showed a slight historical decrease in population; in keeping with the conservative assumptions of this TMDL, no change in the Rocky Mount population was assumed for future conditions. District boundaries were obtained from the Franklin County GIS department (Figure 4.1); historical new permits issued by district were obtained from the Franklin County Permits & Inspections department. Analysis of the historical new permits showed that each year, the relative distribution of growth among the districts remained fairly constant (i.e., although the exact number of new houses changed each year, approximately the same fraction of the total new houses each year were built in each district). Therefore, the 24% increase for all of Franklin County was distributed among the districts according to their average historical contributions to increases in population according to the comprehensive plan (last row in Table 4.5). This resulted in about a 20% increase in population for the portion of the Pigg River watershed in Franklin County. The population per household used in the previous time periods was maintained during this analysis, and to simplify the calculations, the calculations were done on a household basis. The resulting increase in households is shown in Table 4.5; in keeping with conservative assumptions, it was assumed all new houses would be on a septic system (not on a sewer). Each house was also assumed to acquire its standard unit pet.

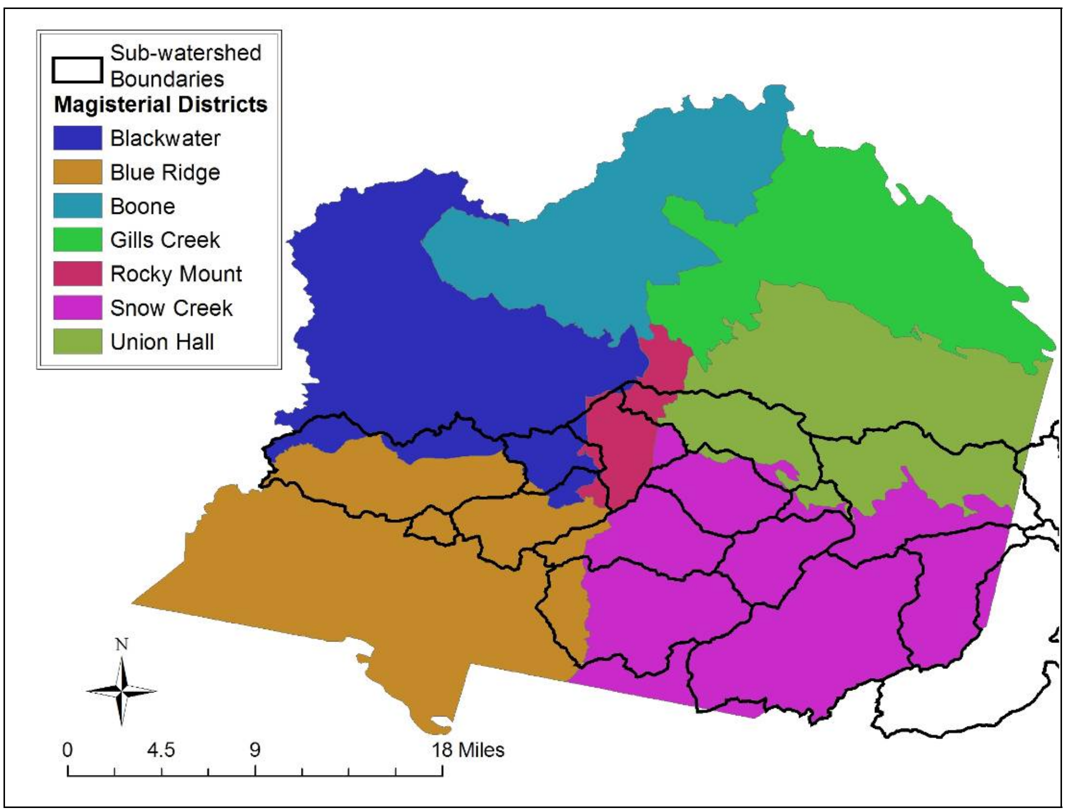

Figure 4.1. Magisterial Districts in Franklin County. District boundaries courtesy of the Franklin County GIS department.

Table 4.5. New houses added for future conditions.

Sub-watershed	Magisterial District				Total
	Blackwater	Blue Ridge	Snow Creek	Union Hall	
4	0	0	0	1	1
9	0	0	29	107	136
10*	0	0	43	0	43
11*	0	0	4	0	4
12*	0	0	117	0	117
13	0	0	6	17	23
14	0	0	42	0	42
15	2	0	12	316	330
16	0	0	91	10	101
17	0	5	69	0	74
18	0	11	99	0	110
19	12	0	22	1	35
20	134	2	0	0	136
21†	23	43	0	0	66
22	33	26	0	0	59
23†	0	16	0	0	16
Total	204	103	534	452	1,293
Calculated 2000-2020 Percent Increase for Entire District	29%	9%	21%	45%	--

*Sub-watersheds are in Snow Creek
†Sub-watersheds are in Story Creek

4.2. Cattle

Fecal coliform in cattle waste can be directly excreted to the stream, or it can be transported to the stream by surface runoff from animal waste deposited on pastures or applied to crops or pasture. Changes occurred in the cattle populations between the calibration, validation, and existing conditions periods. The future conditions were assumed to be the same as the existing conditions; local information suggests that cattle farming is on a decline in the watersheds, but in keeping with conservative assumptions, a steady cattle population for future conditions was assumed.

4.2.1. Distribution of Dairy and Beef Cattle

There are currently 19 dairy farms and 139 beef farms in the Pigg River watershed. The number of dairy farms was initially estimated from information from VDACS and was further refined according to information from Virginia

Cooperative Extension and the Blue Ridge SWCD. The number of beef farms was estimated from communication with extension agents; it was assumed that all were cow-calf operations. Based on watershed reconnaissance, there are no dairy farms and approximately 10 beef farms in the Old Womans Creek watershed.

When possible, dairy farmers were contacted individually to determine the number of cows on each farm. Cow populations for 10 of the 19 farms were determined in this fashion. For the remaining 9 farms (all in Franklin County), estimates were made based on the typical dairy herd size for Franklin County from the USDA National Agricultural Statistics Service (NASS) Census of Agriculture (USDA, 2002). This yielded an estimated 100 lactating cows, 10 dry cows, and 100 heifers per uncontacted farm.

Extension agents provided rough approximations of herd sizes for beef cattle operations. The total number of beef cows modeled throughout the year varied due to the presence or absences of calves and their weights relative to the adult cattle.

Because there are not many dairy operations in this watershed, it is impossible to report the dairy cows on a sub-watershed basis without allowing the reader to tie the numbers to a specific farm. Therefore, to preserve the confidentiality of the dairy farmers personally contacted, the populations for all cattle are reported on the basis of the impaired watersheds (Table 4.6).

Beef and dairy cattle spend varying amounts of time in confinement, streams, and pastures depending on the time of year and type of cattle (e.g., lactating cow vs. heifer). Accordingly, the proportion of fecal coliform deposited in any given land area varies throughout the year. The contacted dairy farmers were asked specifically about their confinement schedules and stream access. According to the Technical Advisory Committee (TAC) and SWCD and VCE personnel, cattle in most beef farms in the Pigg River watershed are not confined. According to these experts, cattle are only confined in one beef farm in Franklin County, and those cattle are confined only minimally, for feeding purposes. Details about Old Womans Creek were unknown, and the default beef confinement schedule was assumed for that watershed. Stream access for all beef farms and the uncontacted dairies was estimated based on the farm's proximity to the stream. A 300 acre circle was drawn around each farm location; if a stream fell within this buffer, it was assumed there was a potential for stream access. The Blue Ridge SWCD identified four beef farmers that had recently put in stream fencing; all other farms with streams in the buffer were assumed to allow cattle access.

Table 4.6. Cattle Populations in Pigg River and Old Womans Creek.

Watershed (sub-watersheds)	Number of Dairy Operations	Dairy Cattle			Number of Beef Operations	Beef cattle
		Lactating	Dry	Heifer		
Lower Pigg (1-7,9,13,15,16)	6	2,323	423	1,100	51	2,410
Upper Pigg (19, 20, 22)	8	762	131	770	19	640
Big Chestnut (14, 17, 18)	0	0	0	0	12	480
Story Creek (21, 23)	2	160	22	167	9	360
Snow Creek (8, 10-12)	3	870	140	460	48	2,080
Old Womans Creek	0	0	0	0	10	248

The following assumptions and procedures were used to estimate the distribution of cattle (and thus, fecal coliform produced by cattle) among different land use types and in the stream:

a) Cows are confined according to the schedule given in Table 4.7. This table reflects the communications with farmers and agency personnel, and is area-weighted to reflect sub-watershed-level confinement.
b) When cattle are not confined, they are on pasture.
c) Cows with stream access (determined as described earlier) will spend varying amounts of time in the stream during different seasons (Table 4.7). Cows spend more time in the stream during the three summer months to protect their hooves from hornflies, among other reasons.

d) Thirty percent of cows in and around streams directly deposit fecal coliform into the stream. The remaining 70% of the feces is deposited on pastures.

Table 4.7. Time spent by cattle in confinement and in the stream.

Month	Fraction of time spent in confinement			Time spent in the stream (hours/day)
	Milk Cows (range; typical)	Dry Cows and Heifers (range; typical)	Beef Cattle (range; typical)	
January	25%-100%; 75%	17%-40%; 40%	0%-40%; 0%	0.5
February	25%-100%; 75%	17%-40%; 40%	0%-40%; 0%	0.5
March	25%-100%; 40%	0%-15%; 0%	0%-0.7%; 0%	0.75
April	25%-100%; 30%	0%-15%; 0%	0%-0.7%; 0%	1
May	25%-100%; 30%	0%-15%; 0%	0%-0.7%; 0%	1.5
June	25%-100%; 30%	0%-15%; 0%	0%-0.7%; 0%	3.5
July	25%-100%; 30%	0%-15%; 0%	0%-0.7%; 0%	3.5
August	25%-100%; 30%	0%-15%; 0%	0%-0.7%; 0%	3.5
September	25%-100%; 30%	0%-15%; 0%	0%-0.7%; 0%	1.5
October	25%-100%; 30%	0%-15%; 0%	0%-0.7%; 0%	1
November	25%-100%; 40%	0%-15%; 0%	0%-0.7%; 0%	0.75
December	25%-100%; 75%	17%-40%; 40%	0%-40%; 0%	0.5

A sample calculation for determining the distribution of cattle to different land use types and to the stream in sub-watershed 22 is shown in Appendix B. The resulting numbers of cattle in each land use type as well as in the stream for all sub-watersheds are given in Table 4.8 for dairy cattle and Table 4.9 and Table 4.10 for beef cattle.

Table 4.8. Distribution of dairy cow (lactating, dry, and heifer) population among the three possible land areas for Pigg River.

Month	Confinement	Pasture	Streams*
January	3649.80	3673.75	4.45
February	3649.80	3673.75	4.45
March	2130.45	5186.39	11.16
April	2002.05	5310.13	15.82
May	2010.63	5293.64	23.72
June	2010.63	5262.01	55.36
July	2010.63	5262.01	55.36
August	2010.63	5262.01	55.36
September	2002.05	5302.23	23.72
October	2002.05	5310.13	15.82
November	2130.45	5186.39	11.16
December	3649.80	3673.75	4.45

*Number of cow equivalent defecations in the stream

Table 4.9. Distribution of beef cow (adult and calf) populations among the three possible land areas for Pigg River.

Month	Confinement	Pasture	Streams*
January	2.90	6830.87	31.73
February	3.40	8018.85	37.25
March	3.50	8237.27	57.53
April	3.60	8454.59	78.91
May	3.70	8650.52	121.68
June	3.81	8719.26	291.64
July	3.91	8950.23	299.36
August	4.01	9181.20	307.09
September	4.11	9592.07	134.92
October	2.52	5912.30	55.18
November	2.65	6222.40	43.46
December	2.77	6533.88	30.35

*Number of cow equivalent defecations in the stream

Table 4.10. Distribution of beef cow (adult and calf) populations among the three possible land areas for Old Womans Creek.

Month	Confinement	Pasture	Streams*
January	114.08	170.86	0.26
February	133.92	200.58	0.30
March	0.00	343.95	0.77
April	0.00	353.58	1.06
May	0.00	362.92	1.64
June	0.00	370.55	3.93
July	0.00	380.37	4.03
August	0.00	390.18	4.14
September	0.00	402.42	1.82
October	0.00	247.26	0.74
November	0.00	259.81	0.59
December	109.12	163.43	0.25

*Number of cow equivalent defecations in the stream

4.2.2. Direct Manure Deposition in Streams

Direct manure loading to streams is due to both dairy (Table 4.8) and beef cattle (Table 4.9, Table 4.10) defecating in the stream. Manure loading increases during the warmer months, when cattle spend more time in water. The potential average annual manure loading directly deposited by cattle in the stream for the entire Pigg River watershed is 2.7×10^6 lb. The load to the stream from cattle in the Old Womans Creek watershed is 3.6×10^4 lb. The associated average daily fecal coliform loading to the stream for the two watersheds is 1.5×10^{12} and 1.6×10^{10} cfu, respectively. The loads for Old Womans Creek will vary according to the amount of flow in the stream (due to the imposed cutoff discussed in the modeling chapter). Part of the fecal coliform deposited in the stream stays suspended, while the remainder adsorbs to the sediment in the streambed. Under base flow conditions, it is likely that suspended fecal coliform bacteria are the primary form transported with the flow. Sediment-bound fecal coliform bacteria are likely to be re-suspended and transported to the watershed outlet under high flow conditions. Die-off of fecal coliform in the stream depends on sunlight, predation, turbidity, and other environmental factors.

4.2.3. Direct Manure Deposition on Pastures

Dairy (Table 4.8) and beef (Table 4.9, Table 4.10) cattle that graze on pastures but do not deposit in streams contribute the majority of fecal coliform loading on pastures. Manure loading on pasture was estimated by multiplying the total number of each type of cattle (milk cow, dry cow, heifer, and beef) on pasture by the amount of manure produced per day. The total amount of manure produced by all types of cattle was divided by the pasture acreage to obtain manure loading (lb/ac-day) on pasture. Fecal coliform loading (cfu/ac-day) on pasture was calculated by multiplying the manure loading (lb/ac-day) by the fecal coliform content (cfu/lb) of the manure. Because the confinement schedule of the cattle changes with season, manure and fecal coliform loading on pasture also change with season.

Pasture has average annual cattle manure loadings of 5,168 lb/ac and 3,837 lb/ac for Pigg River and Old Womans Creek, respectively. The associated fecal coliform loadings from cattle to pasture on a daily basis, averaged over the year, are 2.7×10^9 cfu/ac-day and 1.7×10^9 cfu/ac-day, respectively. Fecal coliform bacteria deposited on the pasture surface are subject to die-off due to desiccation and ultraviolet (UV) radiation. Runoff can transport part of the remaining fecal coliform to receiving waters.

4.2.4. Land Application of Liquid Dairy Manure

A typical milk cow weighs 1,400 lb and produces 17 gal of liquid manure daily (ASAE, 1998). Based on the monthly confinement schedule (Table 4.7) and the number of lactating cows (Table 4.6), annual liquid dairy manure production in the Pigg River watershed is 1.3×10^7 gal. Based on the per capita fecal coliform production of lactating cows, the fecal coliform concentration in fresh liquid manure is 1.18×10^9 cfu/gal. Liquid dairy manure receives priority over other manure types (poultry litter and solid cattle manure) when applied to land. Liquid dairy manure application rates are 6,600 and 6,000 gal/ac-year to cropland and pasture land use categories, respectively, with cropland receiving priority in application. Based on availability of land and liquid dairy manure, as well as the assumptions regarding application rates and priority of application, it was estimated that liquid dairy manure was applied to 1,793 acres (24%) of cropland and 209 acres (0.4%) of pasture.

For modeling purposes, a continuous corn rotation was assumed. This was based on information received from the TAC and personnel at the NRCS. All the corn in Pittsylvania County is in no-till; about 80% of the corn in Franklin County is no-till. Liquid manure is applied to cropland from January through May (prior to planting) and in October through December (after crops are harvested). In cropland applications, liquid manure is applied on the soil surface for no-till corn, and is incorporated into the soil for corn in conventional tillage. Liquid manure can be surface-applied to pasture throughout the year. It was assumed that only 10% of the subsurface-applied fecal coliform was available for removal in surface runoff. The application schedule for manure in Pigg River is given in Table 4.11. This schedule was determined for this area after a detailed phone conversation with Dean Gall, DCR Nutrient Management Specialist. The application schedule in Old Womans Creek was assumed to be the standard application schedule considered by this consultant in previous TMDLs (Table 4.12). Dry cows and heifers were assumed to produce only solid manure.

Table 4.11. Monthly application schedule for Pigg River.

Month	Liquid manure applied (%)*	Solid Manure or poultry litter applied (%)*
January	1	5
February	1	5
March	18	15
April	16	13
May	15	12
June	5	5
July	2	5
August	2	5
September	11	10
October	17	10
November	11	10
December	1	5

*As percent of annual load

Table 4.12. Monthly application schedule for Old Womans Creek.

Month	Liquid manure applied (%)*	Solid Manure or poultry litter applied (%)*
January	0	0
February	5	5
March	25	25
April	20	20
May	5	5
June	10	5
July	0	5
August	5	5
September	15	10
October	5	10
November	10	10
December	0	0

*As percent of annual load

4.2.5. Land Application of Solid Manure

Solid manure produced by dry cows, heifers, and beef cattle during confinement is collected for land application. It was assumed that milk cows produce only liquid manure while in confinement. The number of cattle, their typical weights, amounts of solid manure produced, and fecal coliform concentration in fresh manure are given in Table 4.13. Solid Manure is last on the priority list for application to land (it falls behind liquid manure and poultry litter). The amount of solid manure produced in each sub-watershed was estimated based on the populations of dry cows, heifers, and beef cattle in the sub-watershed (Table 4.1) and their confinement schedules (Table 4.7). Solid manure from dry cows, heifers, and beef cattle contained different fecal coliform concentrations (cfu/lb) (Table 4.13).

Table 4.13. Solid manure production characteristics.

Type of cattle	Population	Typical weight (lb)	Solid manure produced (lb/animal-day)	Fecal coliform concentration in fresh manure (x 10^6 cfu/lb)
Dry cow	716	1,400†	115‡	165§
Heifer	2,497	640††	40.7†	213§
Beef*	5,970; 248	800†	46.4†	207§

†Source: ASAE (1998)
‡Source: MWPS (1993)
§Based on per capita fecal coliform production per day (Table 4.1) and manure production
††Based on weighted average weight assuming that 57% of the animals are older than 10 months (900 lb ea.), 28% are 1.5-10 months (400 lb ea.) and the remainder are less than 1.5 months (110 lb ea.) (MWPS, 1993)
*Population given as Pigg River; Old Womans Creek (recall Old Womans Creek has no dairy operations)

Solid cattle manure is applied at the rate of 15 tons/ac-year to both cropland and pasture, with priority given to cropland. As in the case of liquid manure, solid manure is only applied to cropland during January through May, and October through December. Solid manure can be applied to pasture during the whole year. The incorporation properties of the application of solid manure to cropland or pasture are assumed to be identical to the incorporation properties of the application of liquid dairy manure. The application schedule for solid manure is given in Table 4.11 and Table 4.12. Based on availability of land and solid manure, as well as the assumptions regarding application rates and priority of application, it was estimated that solid cattle manure was applied to 135 acres (2%) of cropland and 67 acres (0.1%) of pasture in Pigg River. It was assumed solid cattle manure was applied to 27 acres (11%) of cropland in Old Womans Creek.

4.2.6. Changes for different time periods

The population of cattle in the watershed is constantly changing. Modifications to these estimates were made for the calibration and validation periods. During the calibration period, compared to existing condition estimates, there were 1,750 fewer dairy cows in the Lower Pigg (reflecting one farmer's present-day dramatic increase in herd size and 3 farmers who went out of business); 210 more dairy cows in the Upper Pigg (reflecting one farmer who went out of business); 347 more dairy cows in Story Creek (reflecting one farmer who went out of business); and 210 more dairy cows in Snow Creek (reflecting one farmer who went out of business). During the validation period, compared to existing condition estimates, there were 50 fewer dairy cows in the Lower Pigg (reflecting another stage of the dramatic increase and one farmer who recently went out of business) and 127 more dairy cows in Story Creek (reflecting one farmer who recently went out of business). As was previously mentioned, four beef farmers have fenced their creeks in the recent past; during both the calibration and validation periods, it was assumed these farms had stream access for their cattle. In keeping with conservative estimation, no changes were made to the cattle populations for future conditions.

4.3. Poultry

The one poultry operation in the Pigg River watershed, located in the Lower Pigg watershed, was located and sized based on information from VCE and the Pittsylvania County SWCD. No poultry operations were located in the Old Womans Creek watershed. Poultry litter production was estimated from the poultry population after accounting for the time during which the house is not occupied.

Because poultry is raised entirely in confinement, all litter produced is collected and stored prior to land application. The estimated production rate of poultry litter in the Pigg River watershed is 9.8×10^4 lb/year; this corresponds to a fecal coliform application rate of 1.64×10^{13} cfu/year. The fecal coliform bacteria produced are subject to die-off in storage and losses due to incorporation prior to being subject to transport via runoff. Poultry litter was applied at the rate of 3 tons/ac-year first to cropland and then to pastures. Poultry litter receives priority after all liquid manure has been applied (i.e., it is applied before solid cattle manure is considered). The incorporation properties of poultry litter application to cropland and pastures are assumed to be identical to the incorporation properties of cattle manure application. The application schedule of poultry litter is given in Table 4.11. As with liquid and solid manures, poultry litter is not applied to cropland during June through September. Based on availability of land and poultry litter, as well as the assumptions regarding application rates and priority of application, it was estimated that poultry litter was applied to 16 acres (0.2%) of cropland.

4.4. Llamas

The llama population for Pigg River (Table 4.1), located entirely in the Upper Pigg River basin, was estimated based on feedback from stakeholders at the first public meeting. There are no llamas in Old Womans Creek. It was assumed that the llamas stayed on pasture at all times, were not confined, and did not defecate in the streams. Thus, all manure and fecal coliform produced by the llamas was deposited directly on pasture. Pasture in the Pigg River watershed receives an average annual manure load of 1.9 lb/ac from llamas. Fecal coliform loadings to pasture from llamas on a daily basis averaged over the year and over all pastures in the watershed are 2.6×10^{7} cfu/ac-day.

4.5. Horses

Horse populations for the Pigg River watershed were estimated from population numbers in the NASS for Franklin, Pittsylvania, and Henry Counties, area-weighted according to pasture areas in the counties and in each sub-watershed of Pigg River. The total horse population was deemed satisfactory by local stakeholders during the public and TAC meetings. The horse populations for Old Womans Creek were estimated based on watershed reconnaissance. The distribution of horses among the sub-watersheds is given in Table 4.14. The fecal coliform originating from horses contributes to the pasture load. Fecal coliform loadings from horses on a daily basis averaged over the year and over all pastures in the watershed are 2.3×10^{6} cfu/ac-day for Pigg River and 4.6×10^{6} cfu/ac-day for Old Womans Creek. During the calibration and validation periods, there were 25 fewer horses in sub-watershed 1; this reflects a horse business that recently came into existence in that sub-watershed.

Table 4.14. Horse Population in Pigg River and Old Womans Creek.

Sub-watershed	Horse Population	Sub-watershed	Horse Population
	Pigg River		
1	45	13	0
2	0	14	5
3	1	15	19
4	5	16	17
5	1	17	12
6	0	18	20
7	14	19	7
8*	1	20	7
9	21	21†	9
10*	15	22	30
11*	22	23†	1
12*	40		
	Old Womans Creek		
1	0	5	2
2	0	6	4
3	5	7	0
4	8		

*Sub-watersheds comprise Snow Creek
†Sub-watersheds comprise Story Creek

4.6. Biosolids

Two companies are currently permitted to discharge biosolids in the watershed. These companies are Robinson Pipe Cleaning/Bionomic Services, Inc. (permit VDHBUR 79) (Franklin County) and S&ME, Inc./Agri-South Biosolid Services, Inc. (permit VDHBUR 44A) (Pittsylvania County). There are currently three farms (266 acres) permitted to receive biosolids in Pittsylvania County and nine farms (1,029.6 acres) permitted to receive biosolids in Franklin County. Missing records made it infeasible to include the historical biosolids application in the calibration and validation of the model. The nature of biosolids application – i.e., the infrequent applications to sites as determined by the needed time for hauling, soil conditions, and weather – made it infeasible to account for the biosolids in the future conditions. For example, the data that were available documented several years when no biosolids applications occurred in the watershed.

Due to the difficulty in obtaining reasonable estimates for the model, a hypothesis was tested in this modeling effort: it was hypothesized that the amount of bacteria contributed by biosolids would be insignificant compared to the bacteria contributed by other sources in the watershed (the other sources discussed in this chapter). To test this hypothesis, data for a well-documented year (1996) were used to create model inputs to the appropriate sub-watersheds. Records of bacteria concentrations, though typically scarce, existed for this year.

Records showed an average bacteria concentration of 68,467 cfu/g for the time period in question. Records showed that biosolids were applied to the watershed only during October of 1996. Biosolids applications occurred over a series of 2 to 7 days in October in various sub-watersheds. To make a conservative test of the hypothesis, it was assumed that biosolids were applied each October of the simulation, and further, that instead of being applied for only 2 to 7 days, they were applied every day during October at the same rate they were actually applied for those 2 to 7 days. The model was then run with and without this new loading. The predicted bacteria concentrations for the two model runs were not noticeably different. Therefore, it was assumed that properly applied biosolids contribute only a negligible amount to the bacteria concentration at the watershed outlets. After this test, biosolids were not explicitly modeled in the existing or future conditions.

4.7. Wildlife

Wildlife fecal coliform contributions can come from excretion of waste on land and from excretion directly into streams. Information provided by VADGIF and watershed residents was used to estimate wildlife populations. Wildlife species that were found in quantifiable numbers in the watershed included deer, raccoon, muskrat, beaver, wild turkey, goose, and wood duck. Population numbers for each species and fecal coliform amounts were determined (Table 4.1) along with preferred habitat and habitat area (Table 4.15).

Professional judgment was used in estimating the percent of each wildlife species depositing directly into streams, considering the habitat area each occupied (Table 4.15). Fecal loading from wildlife was estimated for each sub-watershed. The wildlife populations were distributed among the sub-watersheds based on the area of appropriate habitat in each sub-watershed. For example, the deer population was evenly distributed across the watershed, whereas muskrat and raccoons had variable population densities based on land use and proximity to a water source. Therefore, a sub-watershed with more stream length and impoundments and more area in crop land use would have more muskrats than a sub-watershed with shorter stream length, fewer impoundments, and less area in crop land use. Distribution of wildlife among sub-watersheds is given in Table 4.16 for Pigg River and Table 4.17 for Old Womans Creek.

Table 4.15. Wildlife habitat, population density, and direct fecal deposition in streams.

Wildlife type	Habitat and Estimation Method	Population Density (animal / mi² -habitat)	Direct fecal deposition in streams (%) (larger streams; smaller streams)
Deer	Entire Watershed	30	0.5%; 0.25%
Raccoon	low density on forests not in high density area; high density on forest within 600 ft of a permanent water source or 0.5 mile of cropland; highest density in residential areas	Low density: 10 High density: 30 Highest density: 50	5%; 2.5%
Muskrat	16/mile of ditch or medium sized stream intersecting cropland; 8/mile of ditch or medium sized stream intersecting pasture; 10/mile of pond or lake edge; 50/mile of slow-moving river edge	-see habitat column-	12.5%; 6.25%
Beaver	3/mile of Pigg River perennial streams; 2/mile of Old Womans Creek perennial streams; and 3.8/mile of lake or pond shore	-see habitat column-	25%; 12.5%
Geese	300 ft buffer around main streams	50 – off season 70 – peak season	12.5%; 6.25%
Wood Duck	300 ft buffer around main streams	40 – off season 60 – peak season	12.5%; 6.25%
Wild Turkey	Forest; based on kill rate per square mile of forest for each county, assuming the killed birds are 10% of the total population	12.43 (Franklin) 7.4 (Henry) 7.6 (Pittsylvania)	0%; 0%

Table 4.16. Wildlife populations in Pigg River.

Sub-watershed	Deer	Raccoon	Muskrat	Beaver	Goose		Wood Duck		Wild Turkey
					Off-peak	Peak	Off-peak	Peak	
1	1,236	1,001	385	160	415	581	332	498	237
2	78	68	1	12	21	30	17	26	17
3	29	21	2	5	9	13	7	11	5
4	356	318	22	43	92	129	74	111	72
5	37	32	20	4	8	11	6	9	7
6	232	146	49	35	68	95	54	82	29
7	515	343	3	57	161	226	129	193	83
8*	29	30	54	5	8	12	7	10	5
9	1,094	862	32	134	353	494	282	423	340
10*	569	369	52	80	166	232	133	199	158
11*	1,149	865	160	131	348	487	278	417	226
12*	1,357	827	4	137	436	610	348	523	376
13	100	68	29	12	27	37	21	32	28
14	400	321	63	56	148	207	119	178	138
15	588	427	51	83	212	297	170	255	141
16	425	258	44	47	109	153	87	131	98
17	528	416	120	63	156	219	125	187	160
18	914	611	13	103	334	468	267	401	288
19	376	282	17	38	105	147	84	126	105
20	229	151	43	25	81	113	65	97	60
21†	460	439	93	44	138	193	111	166	149
22	1,021	729	5	100	252	353	202	303	351
23†	71	81	0	4	11	16	9	14	22
Total	11,793	8,665	1,262	1,378	3,658	5,123	2,927	4,392	3,095

*Sub-watersheds comprise Snow Creek
†Sub-watersheds comprise Story Creek

Table 4.17. Wildlife populations in Old Womans Creek.

Sub-watershed	Deer	Raccoon	Muskrat	Beaver	Goose		Wood Duck		Wild Turkey
					Off-peak	Peak	Off-peak	Peak	
1	3	2	0	0	1	2	1	1	1
2	15	12	1	2	7	10	6	8	3
3	3	3	1	1	1	2	1	2	1
4	115	80	15	3	29	40	23	34	20
5	108	79	4	6	21	29	17	25	19
6	88	60	3	5	19	26	15	22	18
7	58	36	4	3	19	27	15	23	13
Total	390	272	28	20	97	136	78	115	75

Land use change was modeled for future conditions in the Pigg River watershed. As a result, populations for those animals whose habitat is affected by land use changes (raccoons, muskrats, and wild turkeys, Table 4.15) were recalculated for future conditions. The *changes* in populations from the existing conditions presented in Table 4.16 to the future conditions modeled in the allocation scenarios are presented in Table 4.18.

Table 4.18. Changes in wildlife populations for future conditions.

Sub-watershed	Change in Raccoon Population	Change in Muskrat Population	Change in Wild Turkey Population
9			-3
12*	+5	-4	-3
15	+32	-1	-12
16	+18		-10
17	+9	-3	-12
19	+129	-11	-67
20	+38	-7	-24
21†	+126	-33	-56
22	+1		-1
23†	+7	-2	-4
Total	+365	-61	-192

*Sub-watershed is in Snow Creek
†Sub-watersheds comprise Story Creek

4.8. Summary: Contributions from All Sources

Based on the inventory of sources discussed in this chapter, a summary of the contribution by the different direct nonpoint sources to the annual fecal coliform loading to the streams is given in Table 4.19. Distribution of annual fecal coliform loading from nonpoint sources among the different land use categories is also given in Table 4.19.

From Table 4.19, it is clear that nonpoint source loadings to the land surface are nearly 70 or 100 times (for Pigg River and Old Womans Creek, respectively) greater than direct nonpoint source loadings to the stream. Pastures receive the greatest portion of this load, at around 80% for both watersheds. However, factors such as precipitation amount and pattern, die-off rates, manure application activities, type of waste, and proximity to the streams impact the amount of fecal coliform from upland areas that reaches the streams. Due to their nature, direct nonpoint source loadings to streams are not modified before transmission to the stream. The HSPF model discussed in Chapter 5 considers these factors when estimating fecal coliform loadings in the receiving waters.

Table 4.19. Annual fecal coliform loadings to the stream and the various land use categories for the Pigg River and Old Womans Creek watersheds.

Source	Fecal coliform loading ($x10^{12}$ cfu/yr)		Percent of total loading	
	Pigg River	Old Womans Creek	Pigg River	Old Womans Creek
Direct loading to streams				
Cattle in stream	547	5.7	<1%	<1%
Wildlife in stream	377	7.7	<1%	<1%
Straight pipes	25	0	<1%	0%
Loading to land surfaces				
Cropland	542	6.8	<1%	<1%
Pasture	54,189	1,080	82%	80%
Residential	5,196	92	8%	7%
Forest	5,459	156	8%	12%
Total	66,335	1,348		

Chapter 5: Modeling Process for Bacteria TMDL Development

A key component in developing a TMDL is establishing the relationship between pollutant loadings (both point and nonpoint) and in-stream water quality conditions. Once this relationship is developed, management options for reducing pollutant loadings to streams can be assessed. In developing a TMDL, it is critical to understand the processes that affect the fate and transport of the pollutants and cause the impairment of the waterbody of concern. Pollutant transport to water bodies is evaluated using a variety of tools, including monitoring, geographic information systems (GIS), and computer simulation models. In this chapter, the modeling process, input data requirements, and model calibration procedure and results are discussed.

5.1. Model Description

The TMDL development process requires the use of a watershed-based model that integrates both point and nonpoint sources and simulates in-stream water quality processes. The Hydrologic Simulation Program – FORTRAN (HSPF) version 12 (Bicknell et al., 2001; Duda et al., 2001) was used to model fecal coliform transport and fate in the Pigg River and Old Womans Creek watersheds. The ArcGIS 9.1 GIS program was used to display and analyze landscape information for the development of input for HSPF.

The HSPF model simulates nonpoint source runoff and pollutant loadings, performs flow routing through streams, and simulates in-stream water quality processes. HSPF estimates runoff from both pervious and impervious parts of the watershed and stream flow in the channel network. The sub-module PWATER within the module PERLND simulates runoff, and hence, estimates the water budget, on pervious areas (e.g., agricultural land). Runoff from impervious areas is modeled using the IWATER sub-module within the IMPLND module. The simulation of flow through the stream network is performed using the sub-modules HYDR and ADCALC within the module RCHRES. While HYDR routes the water through the stream network, ADCALC calculates variables used for simulating convective transport of the pollutant in the stream. Fate of fecal coliform on pervious and impervious land segments is simulated using the PQUAL (PERLND module) and IQUAL (IMPLND module) sub-modules, respectively. Fate of fecal coliform in stream water is simulated using the general constituent pollutant (GQUAL) sub-module within RCHRES module. Fecal coliform bacteria are simulated as dissolved pollutants in the GQUAL sub-module.

5.2. Input Data Requirements

The HSPF model requires a wide variety of input data to describe hydrology, water quality, and land use characteristics of the watershed. The different types and sources of input data used to develop the TMDLs for the Pigg River, Snow Creek, Story Creek, and Old Womans Creek watersheds are discussed below.

5.2.1. Climatological Data

Hourly precipitation data were obtained from the Rocky Mount weather station in Franklin County, located inside the northern part of the watershed (sub-watershed 19). These data had many holes and were patched with data from the nearby Chatham weather station in Pittsylvania County. Because data for some parameters needed by HSPF were not available at Rocky Mount, data from Roanoke Regional Airport and Lynchburg Airport were also used to complete the meteorological data set required for running HSPF. Detailed descriptions of the weather data and the procedure for converting the raw data into the required data set are presented in Appendix D.

5.2.2. Model Parameters

The hydrology parameters required by HSPF were defined for every land use category for each sub-watershed. Required hydrology parameters are listed in the HSPF Version 12 User’s Manual (Bicknell et al., 2001). Initial estimates for required hydrology parameters were generated based on guidance in BASINS

Technical Note 6 (USEPA, 2000a); these parameters were refined during calibration. Each reach requires a function table (FTABLE) to describe the relationship between water depth, surface area, volume, and discharge (Bicknell et al., 2001). A research project in Summer 2004 generated detailed cross-section surveys for most cross-section profiles in Pigg River (Bright et al., 2004); these were used to generate FTABLEs where available. Redelineation of the sub-watershed boundaries near the beginning of the TMDL project left some sub-watersheds without detailed cross-sections; for these sub-watersheds, the FTABLE parameters were estimated using a digital elevation model (DEM) of the area in addition to relationships developed by the NRCS that relate stream characteristics to drainage area according to the procedure described in Staley et al. (2006). A visual assessment of stream characteristics was completed for the Old Womans Creek as part of a graduate class project at Virginia Tech in Fall 2003; this assessment was used to develop FTABLEs for Old Womans Creek. Stream lengths and slopes were determined using GIS data. Information on the calculated stream geometry for each sub-watershed is presented in Table 5.1 for Pigg River and Table 5.2 for Old Womans Creek for the bankfull condition.

Required water quality parameters are also given in the HSPF User's Manual (Bicknell et al., 2001). Initial estimates for bacteria loading parameters were based on estimates of bacteria production in the watershed; estimates of die-off rates and subsurface bacteria concentrations were based on values commonly used in previous TMDLs.

Table 5.1. Reach characteristics for Pigg River.

Sub-watershed	Stream length (mile)	Average bankfull width (ft)	Average bankfull channel depth (ft)	Slope (ft/ft)
1*	8.60	129	9	0.0011
2*	2.45	123	9	0.00085
3*	1.55	31	3	0.0022
4*	5.37	120	9	0.00088
5*	1.40	41	4	0.0024
6*	4.29	30	3	0.0093
7*	8.19	40	4	0.0077
8†	1.56	52	1	0.0000012
9	15.58	84	2	0.0010
10†	9.47	37	2	0.0019
11†	15.73	31	1	0.0041
12†	15.19	28	1	0.0050
13	4.01	66	1	0.0024
14	12.62	51	1	0.0018
15	17.28	60	2	0.0015
16	6.51	26	2	0.0070
17	11.95	20	1	0.0090
18	15.07	26	1	0.0050
19	10.22	60	4	0.0016
20*	5.50	56	5	0.0020
21‡	9.53	23	1	0.0039
22	13.48	34	1	0.0141
23*‡	1.98	19	2	0.0212

*Bankfull characteristics determined from NRCS method
†Sub-watersheds comprise Snow Creek
‡Sub-watersheds comprise Story Creek

Table 5.2. Reach characteristics for Old Womans Creek.

Sub-watershed	Stream length (mile)	Average bankfull width (ft)	Average bankfull channel depth (ft)	Slope (ft/ft)
1	0.16	10	1	0.014
2	1.24	5.5	0.5	0.029
3	0.30	10	1	0.004
4	1.59	5.5	0.5	0.010
5	2.83	5.75	1.25	0.0060
6	2.47	4	1	0.016
7	1.58	2.25	0.3	0.022

5.3. Accounting for Pollutant Sources

5.3.1. Overview

There are two VPDES facilities currently in operation that are permitted to discharge bacteria into Story Creek and Pigg River: Ferrum Town STP (VA0029254) and Rocky Mount Town STP (VA0085952). During calibration and validation, reported bacteria concentrations discharged by these facilities were used as input to the model. An additional permit (VA0091103) exists for the Franklin County Commerce Center WWTP, yet to go online. During future conditions, flow from all three facilities was modeled at their design flows and bacteria concentrations were modeled at their permitted limits (126 cfu/100 mL) (Table 4.2). Recall no permitted facilities exist in the Old Womans Creek watershed.

Bacteria loads that are directly deposited by cattle, wildlife, and straight pipes directly into streams were treated as direct nonpoint sources in the model. Direct nonpoint source loadings were applied to the stream reach in each sub-watershed as appropriate. The point sources permitted to discharge bacteria in the watershed were incorporated into the simulations at the stream locations designated in their permits.

Bacteria that were land-applied or deposited on land were treated as nonpoint source loadings; all or part of that load may be transported to the stream as a result of surface runoff during rainfall events. The nonpoint source loading was applied in the model in the form of fecal coliform counts to individual land use categories by sub-watershed. Fecal coliform die-off in storage was accounted for prior to generating the input for the model. Fecal die-off while the bacteria lay on the land and were transported down the stream were simulated within the model. Both direct nonpoint and nonpoint source loadings were varied by month to account for seasonal differences in bacteria production and deposition characteristics, such as migratory behavior, management practices, and cattle time in streams.

We used an internally-developed spreadsheet program, the Bacteria Source Load Calculator (Zeckoski et al., 2005), to generate nonpoint source fecal coliform inputs to the HSPF model. This spreadsheet program takes inputs of animal numbers, land use, and management practices by subwatershed an outputs hourly direct deposition to streams and monthly loads to each land use type. The BSLC allows direct deposition in the stream by cattle, ducks, and geese to occur only during daylight hours. The BSLC calculates the manure produced in confinement be each animal type (dairy cows, beef cattle, and poultry) and distributes this manure to available lands (crops and pasture) within each sub-watershed. If a sub-watershed does not have sufficient land to apply all the manure its animals generate, the excess manure is distributed equally to other sub-watersheds that have land that has not yet received manure.

5.3.2. Modeling fecal coliform die-off

Fecal coliform die-off was modeled using first order die-off of the form:

$$C_t = C_o 10^{-kt} \qquad [5.1]$$

Where: C_t = concentration or load at time t;

C_o = starting concentration or load;

k = decay rate (day^{-1});

and t = time in days.

A review of literature provided estimates of decay rates that could be applied to waste storage and handling in the watersheds (Table 5.3).

Table 5.3. First order decay rates for different animal waste storage.

Waste type	Storage/application	Decay rate (day^{-1})	Reference
Dairy manure	Pile (not covered)	0.066	Crane and Moore (1986)
	Pile (covered)	0.028	
Beef manure	Anaerobic lagoon	0.375	Crane and Moore (1986)
Poultry litter	Soil surface	0.035	Giddens et al. (1973)
		0.342	Crane et al. (1980)

Based on the values cited in the literature (Table 5.3), the following decay rates were used in simulating fecal coliform die-off in stored waste.

- Liquid dairy manure: Because the decay rate for liquid dairy manure storage could not be found in the literature, the decay rate for beef manure in anaerobic lagoons (0.375 day^{-1}) was used.
- Solid cattle manure: Based on the range of decay rates (0.028-0.066 day^{-1}) reported for solid dairy manure, a decay rate of 0.05 day^{-1} was used, assuming that a majority of manure piles are not covered.
- Poultry waste in pile/house: Because no decay rates were found for poultry waste in storage, a decay rate of 0.035 day^{-1} was used based on the lower decay rate reported for poultry litter applied to the soil surface. The lower value was used instead of the higher value because fecal coliform die-off in storage was assumed to be lower, given the absences of UV radiation and predation by soil microbes.

The procedure for calculating fecal coliform counts in waste at the time of land application is included in Appendix C. The fraction of fecal coliform surviving in the manure at the end of storage is calculated depending on the duration of storage, type of storage, type of manure, and die-off factor. The daily addition of fresh manure and the fecal coliform die-off for each fresh manure addition is considered to arrive at an effective survival fraction over the entire storage period. The amount of fecal coliform available for application to land per year is estimated by multiplying the survival fraction by the total fecal coliform produced per year in confinement. Monthly fecal coliform application to land is estimated by multiplying the amount of fecal coliform available for application to land per year by the fraction of manure applied to land during that month. A base-10 decay rate of 0.05 day^{-1} was assumed for fecal coliform on the land (whether those coliform were directly deposited by animals or applied to the land after storage). Using equation 5.1, with a constant daiy input of bacteria, the total bacteria on the soil surface will eventually reach an asymptotic limit directly proportional to that daily addition. HSPF uses this relationship to define die-off in on the land surface in the model: a decay rate of 0.05 day^{-1} is represented in HSPF by specifying a maximum surface buildup of nine times the daily loading rate. The in-stream decay rate was calibrated to be 1.15 day^{-1} for Old Womans Creek, 0.85 day^{-1} for tributaries to Pigg River, and 0.75 day^{-1} for the main branch of Pigg River starting below Rocky Mount.

5.3.3. Modeling Nonpoint Sources

For modeling purposes, nonpoint fecal coliform loads were those that were deposited or applied to land, and hence, required surface runoff events for transport to streams. Fecal coliform loading by land use for all sources in each sub-watershed is presented in Chapter 4. The existing condition fecal coliform loads are based on best estimates of existing wildlife, livestock, and human populations and fecal coliform production rates. Fecal coliform in stored waste was adjusted for die-off prior to the time of land application when calculating loadings to cropland and pasture, as described in the preceding section. Fecal coliform loadings to each sub-watershed in the Pigg River and Old Womans Creek watersheds are presented in Appendix F for future conditions. The sources of fecal coliform to different land use categories and how the model handled them are briefly discussed below.

1. Cropland: Liquid dairy manure and solid manure are applied to cropland as described in Chapter 4. Fecal coliform loadings to cropland were adjusted to account for die-off during storage and partial incorporation during land application. Wildlife contributions were also added to the cropland areas. For modeling, the monthly fecal coliform loading assigned to cropland was distributed over the entire cropland acreage within a sub-watershed. Thus, loading rate varied by month and sub-watershed.
2. Pasture: In addition to direct deposition from livestock and wildlife, pastures receive applications of liquid dairy manure and solid manure as described in Chapter 4. Applied fecal coliform loading to pasture was reduced to account for die-off during storage. For modeling, the

monthly fecal coliform loading assigned to pasture was distributed over the entire pasture acreage within a sub-watershed.

3. Low Density Residential: Fecal coliform loading on rural residential land uses came from failing septic systems and waste from pets. In the model simulations, fecal coliform loads produced by failing septic systems and pets in a sub-watershed were combined and assumed to be uniformly applied to the low density residential pervious land use areas. Impervious areas (Table 3.1) received constant loads of 1.0 x 10^7 cfu/acre/day.
4. High-Density Residential: Fecal coliform loading to the high density residential land use came from pets in these areas; the impervious load was assumed to be a constant 1.0 x 10^7 cfu/acre/day (USEPA, 2000b).
5. Forest: Wildlife not defecating in streams, cropland, or pastures provided fecal coliform loading to the forested land use. Fecal coliform from wildlife in forests was applied uniformly over the forest areas in each sub-watershed.

5.3.4. Modeling Direct Nonpoint Sources

Fecal coliform loads from direct nonpoint sources included cattle in streams, wildlife in streams, and direct loading to streams from straight pipes from residences. Loads from direct nonpoint sources in each sub-watershed are described in detail in Chapter 4. Contributions of fecal coliform from interflow and groundwater were modeled as having a constant concentration of 15 cfu/100mL for interflow and 10 cfu/100mL for groundwater.

5.4. Model Calibration and Validation

Model calibration is the process of selecting model parameters that provide an accurate representation of the watershed. In this section, the procedures followed for calibrating the hydrology and water quality components of the Hydrological Simulation Program-FORTRAN (HSPF) model are discussed.

5.4.1. Hydrology

The HSPEXP decision support system developed by USGS was used to calibrate the hydrologic portion of HSPF for Pigg River. The default HSPEXP criteria for evaluating the accuracy of the flow simulation were used in the calibration for Pigg River. These criteria are listed in Table 5.4. After calibration, all criteria listed in Table 5.4 were met.

Table 5.4. Default criteria for HSPEXP.

Variable	Percent Error Criteria
Total Volume	10%
50% Lowest Flows	10%
10% Highest Flows	15%
Storm Peaks	15%
Seasonal Volume Error	10%
Summer Storm Volume Error	15%

The hydrologic calibration period was September 1, 1989 to December 31, 1995. The hydrologic validation period was from June 1, 1984 to August 31, 1989. The output from the HSPF model for both calibration and validation was daily average flow in cubic feet per second (cfs). Calibration parameters were adjusted within the recommended range (USEPA, 2000a).

The simulated flow for both the calibration and validation matched the observed flow well, as shown in Figure 5.1 and Figure 5.2. The agreement with observed flows is further illustrated in Figure 5.3 and Figure 5.4 for a representative year and Figure 5.5 and Figure 5.6 for a representative storm. The agreement between the simulated and observed time series can be further seen through the comparison of their cumulative frequency curves (Figure 5.7 and Figure 5.8).

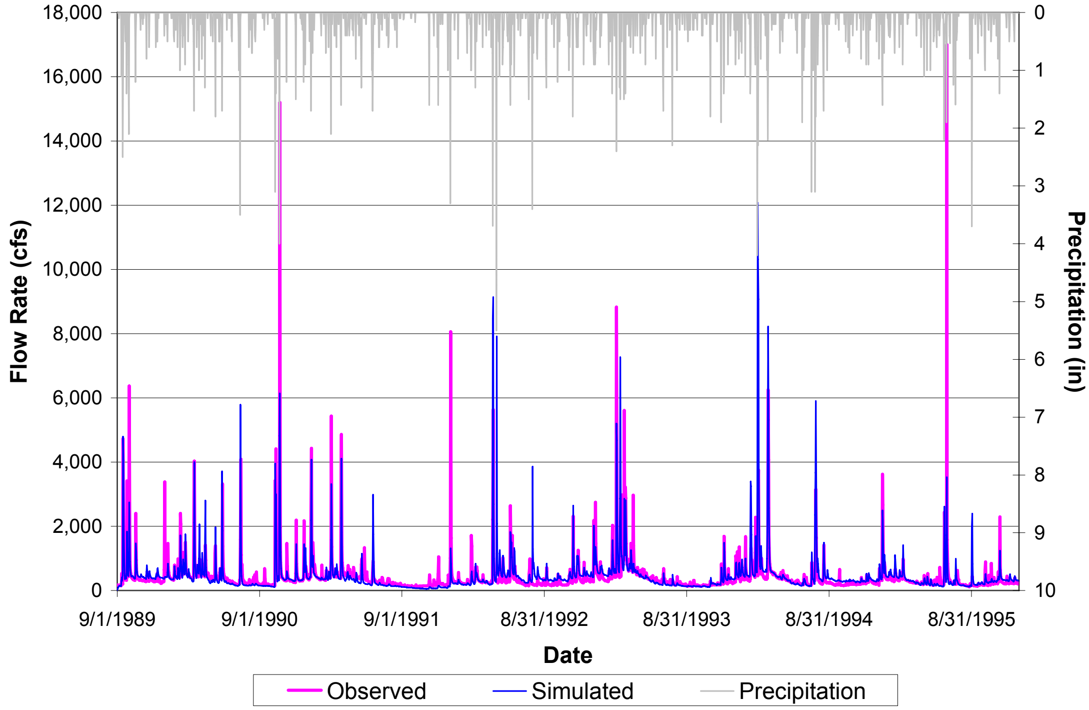

Figure 5.1. Observed and simulated flows and precipitation for Pigg River during the calibration period.

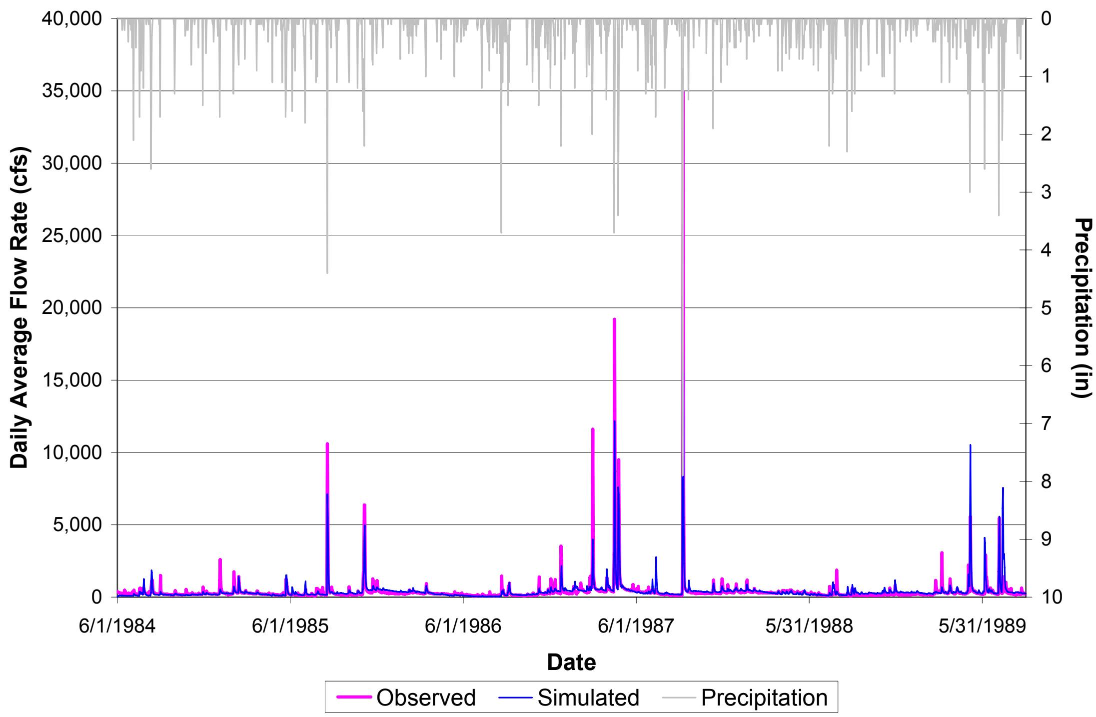

Figure 5.2. Observed and simulated flows and preciptiation for Pigg River during the validation period.

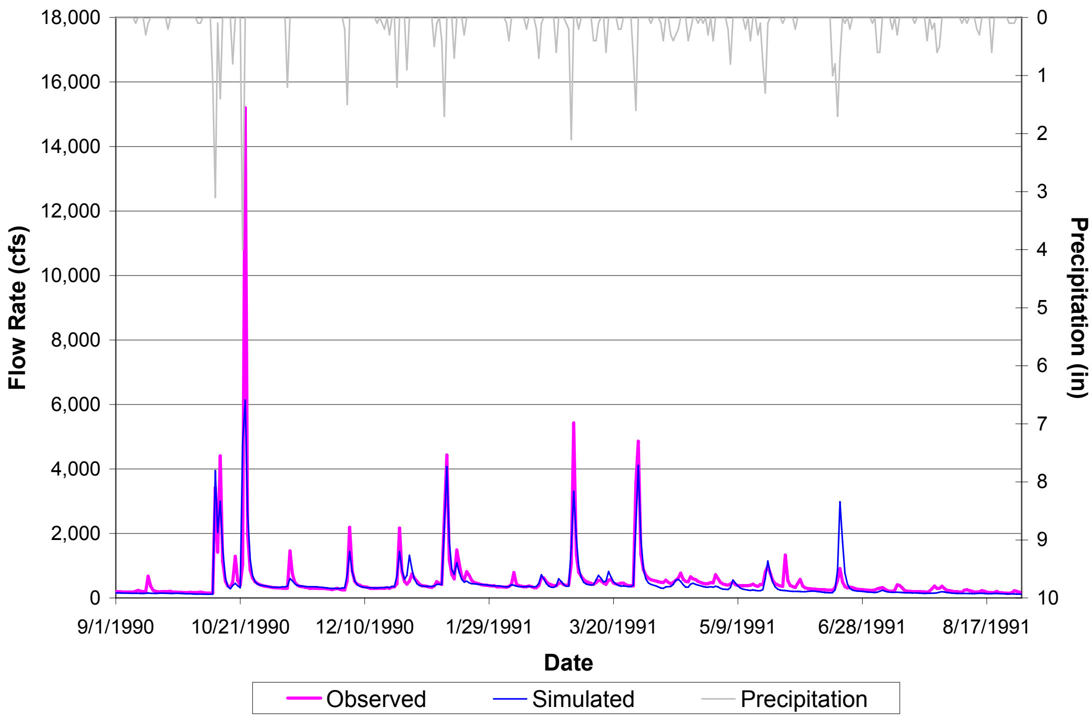

Figure 5.3. Observed and simulated flows and precipitation for a representative year in the calibration period for Pigg River.

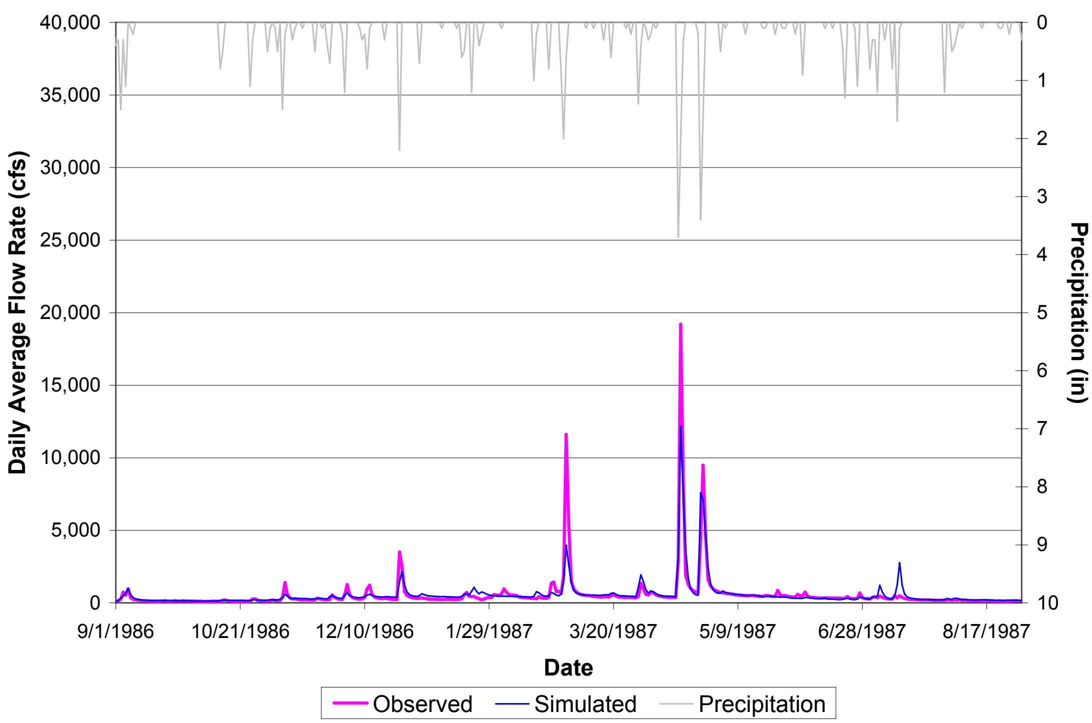

Figure 5.4. Observed and simulated flows and precipitation for a representative year in the validation period for Pigg River.

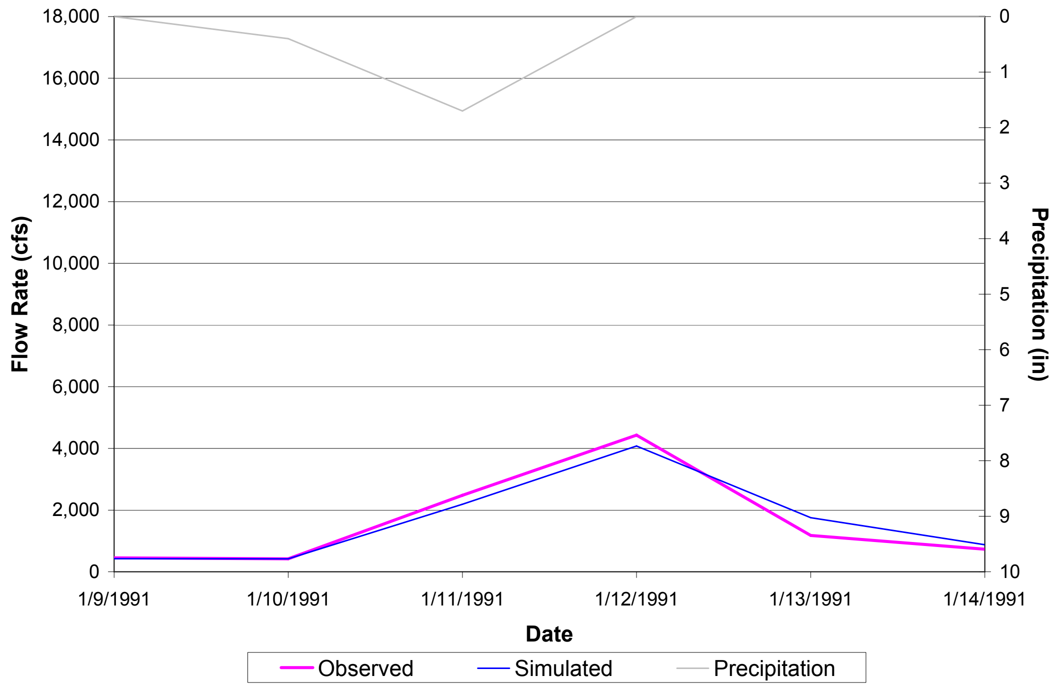

Figure 5.5. Observed and simulated flows and precipitation for Pigg River for a representative storm in the calibration period.

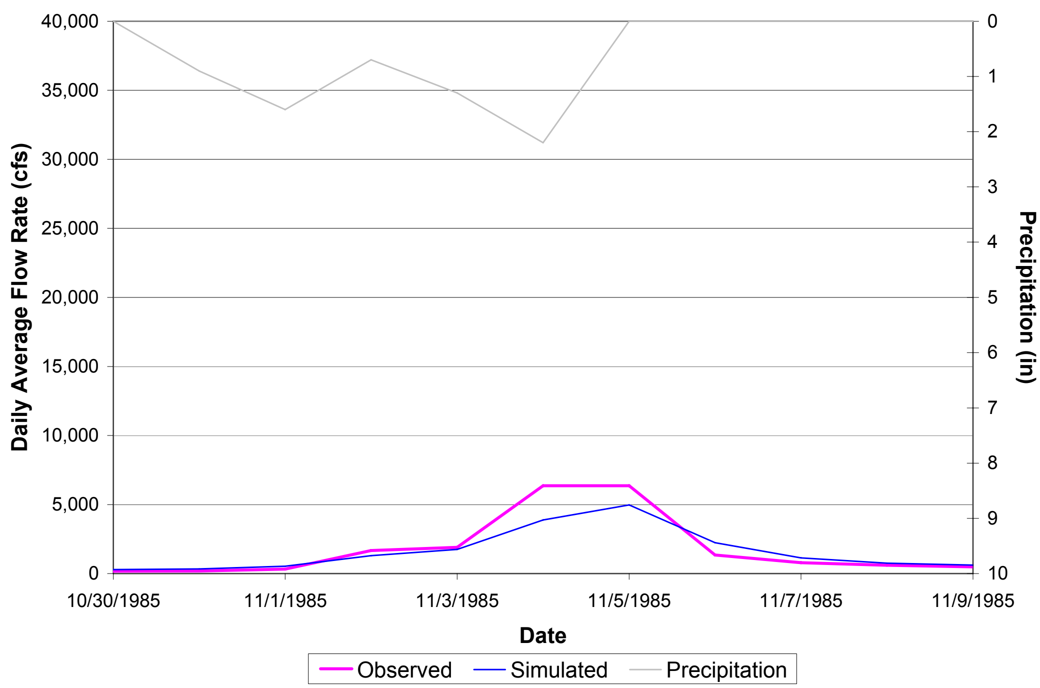

Figure 5.6. Observed and simulated flows and precipitation for Pigg River for a representative storm in the validation period.

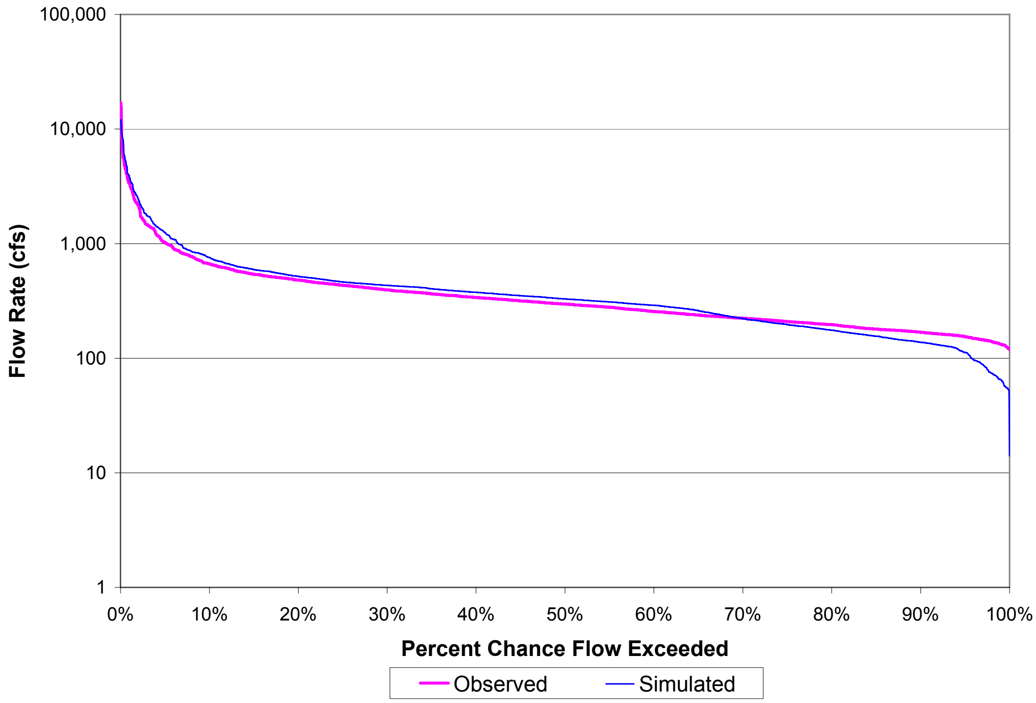

Figure 5.7. Cumulative frequency curves for the calibration period for Pigg River.

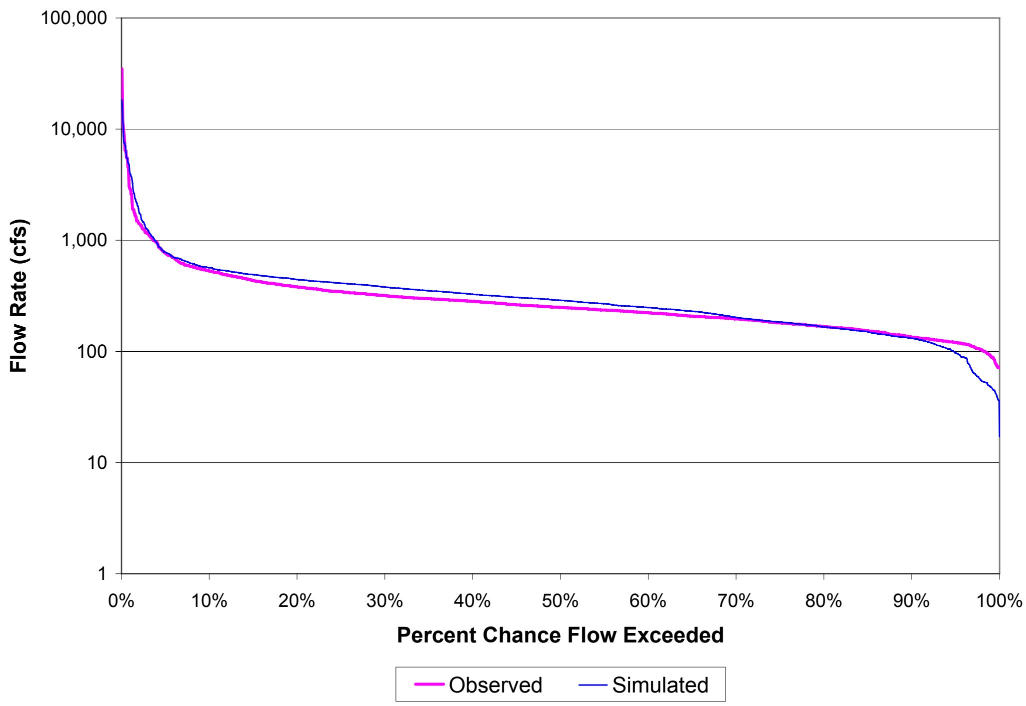

Figure 5.8. Cumulative frequency curves for the validation period for Pigg River.

Selected diagnostic output from the HSPEXP program is listed in Table 5.5 and Table 5.6. The total winter runoff and total summer runoff errors are considered in the HSPEXP term ‘seasonal volume error’ (see Table 5.4). The errors for seasonal volume error were 2.5% for the calibration period and 1.8% for the validation period; both are within the required range of ±10%.

Table 5.5. Summary statistics for the calibration for Pigg River.

	Simulated	Observed	Error (%)	Criterion
Total Runoff (in)	116.500	108.064	+7.8	10%
Average Annual Total Runoff (in)	18.404	17.072	+7.8	10%
Total of Highest 10% of flows (in)	46.34	40.92	+13.2	15%
Total of Lowest 50% of flows (in)	25.180	26.044	-3.3	10%
Total Winter Runoff (in)	30.130	29.486	+2.2	na
Total Summer Runoff (in)	20.500	20.359	+0.7	na
Coefficient of Determination, r^2	0.37			

na = not applicable; these are not criteria directly considered by HSPEXP

Table 5.6. Summary statistics for the validation period for Pigg River.

	Simulated	Observed	Error (%)	Criterion
Total Runoff (in)	84.660	79.077	+7.1	10%
Average Annual Total Runoff (in)	16.126	15.062	+7.1	10%
Total of Highest 10% of flows (in)	34.070	33.280	+2.4	15%
Total of Lowest 50% of flows (in)	18.690	18.223	+2.6	10%
Total Winter Runoff (in)	19.700	17.331	+13.7	na
Total Summer Runoff (in)	20.240	18.255	+10.9	na
Coefficient of Determination, r^2	0.57			

na = not applicable; these are not criteria directly considered by HSPEXP

Flow partitioning for the Pigg River hydrologic model calibration and validation is shown in Table 5.7. When the observed flow data were evaluated using HYSEP, the baseflow indices for the calibration and validation periods were 0.61 and 0.60, respectively. The baseflow indices for the simulated data are presented in Table 5.7. We feel the simulated baseflow indices shown in Table 5.7 match the observed values well. The final calibrated hydrology parameters can be found at the end of the next section.

Table 5.7. Flow partitioning for the calibration and validation periods for Pigg River.

Average Annual Flow	Calibration	Validation
Total Annual Runoff (in)	18.40	16.13
Surface Runoff (in)	3.68 (20%)	2.91 (18%)
Interflow (in)	3.23 (18%)	2.86 (18%)
Baseflow (in)	11.49 (62%)	10.36 (64%)
Baseflow Index	0.62	0.64

The calibration met all the acceptance criteria in both the calibration and the validation period. This indicates that the developed hydrologic model provides and acceptable prediction of Pigg River flows. Recall that no flow gage existed on Old Womans Creek, and therefore the calibrated hydrologic parameters from Pigg River were used in the model for Old Womans Creek.

Table 5.8. Final calibrated hydrology parameters for Pigg River.

Parameter	Definition	Units	FINAL CALIBRATION	FUNCTION OF…	Appendix E Table (if applicable)
PERLND					
PWAT-PARM2					
FOREST	Fraction forest cover	none	1.0 forest, 0.0 other	Forest cover	
LZSN	Lower zone nominal soil moisture storage	inches	9.0	Soil properties	
INFILT	Index to infiltration capacity	in/hr	0.096-0.245[a]	Soil and cover conditions	1
LSUR	Length of overland flow	feet	91-500	Topography	1
SLSUR	Slope of overland flowplane	none	0.01-0.205	Topography	1
KVARY	Groundwater recession variable	1/in	0.0	Calibrate	
AGWRC	Base groundwater recession	none	0.99	Calibrate	
PWAT-PARM3					
PETMAX	Temp below which ET is reduced	deg. F	40	Climate, vegetation	
PETMIN	Temp below which ET is set to zero	deg. F	35	Climate, vegetation	
INFEXP	Exponent in infiltration equation	none	2	Soil properties	
INFILD	Ratio of max/mean infiltration capacities	none	2	Soil properties	
DEEPFR	Fraction of GW inflow to deep recharge	none	0.10	Geology	
BASETP	Fraction of remaining ET from baseflow	none	0.15	Riparian vegetation	
AGWETP	Fraction of remaining ET from active GW	none	0.10	Marsh/wetlands ET	

Table 5.8. Final calibrated hydrology parameters for Pigg River. (continued)

Parameter	Definition	Units	FINAL CALIBRATION	FUNCTION OF…	Appendix E Table (if applicable)
PWAT-PARM4					
CEPSC	Interception storage capacity	inches	monthly[b]	Vegetation	2
UZSN	Upper zone nominal soil moisture storage	inches	monthly[b]	Soil properties	3
NSUR	Mannings' n (roughness)	none	0.37 forest and pasture; 0.27 crop; 0.10 LDR; 0.05 HDR	Land use, surface condition	
INTFW	Interflow/surface runoff partition parameter	none	1.0	Soils, topography, land use	
IRC	Interflow recession parameter	none	0.3	Soils, topography, land use	
LZETP	Lower zone ET parameter	none	monthly[b]	Vegetation	4
IMPLND					
IWAT-PARM2					
LSUR	Length of overland flow	feet	150	Topography	
SLSUR	Slope of overland flowplane	none	0.08	Topography	
NSUR	Mannings' n (roughness)	none	0.08	Land use, surface condition	
RETSC	Retention/interception storage capacity	inches	0.100	Land use, surface condition	
IWAT-PARM3					
PETMAX	Temp below which ET is reduced	deg. F	40	Climate, vegetation	
PETMIN	Temp below which ET is set to zero	deg. F	35	Climate, vegetation	
RCHRES					
HYDR-PARM2					
KS	Weighting factor for hydraulic routing		0.5		

[a]Varies with land use

[b]Varies by month and with land use

5.4.2. Water Quality Calibration and Validation

The water quality calibration for all watersheds in this study was performed at an hourly time step using the HSPF model. Observed water quality data for Pigg River and its tributaries were available for many stations throughout the watershed. Eight monitoring stations were chosen for the calibration and validation of Pigg River; these stations and the rationale for their selection are presented in Table 5.9. Two stations with adequate data for calibration/validation existed in the Old Womans Creek watershed; both were used during the calibration and/or validation (Table 5.9). The station locations are shown in Figure 3.1 and described in Table 3.6.

Table 5.9. Stations used in the water quality calibration/validation for Pigg River and Old Womans Creek; data presented for entire period of record.

Station ID	Number of Observations	Violation Rate*	Rationale for Choosing this Station
4ASDA000.67	9	44%	Station is located at outlet of Story Creek; BST Station
4ASDA009.79	121	54%	Station that caused 303(d) listing for Story Creek
4ASNW000.6	66	27%	Station that caused 303(d) listing for Snow Creek; BST station
4ACNT001.32	21	9.5%	Station shows lower bacteria concentrations than other watershed stations
4APGG003.29	70	36%	Located at Watershed Outlet; Station caused 303(d) listing for Pigg River; BST Station
4APGG030.62	50	26%	BST Station
4APGG052.73	123	41%	Long period of record; Station caused 303(d) listing for Pigg River; BST Station
4APGG068.49	21	29%	BST Station
4AOWC002.35	9	22%	Station is located at outlet of Old Womans Creek; BST Station
4AOWC005.36	45	29%	Station that caused 303(d) listing for Old Womans Creek

*Violation rate of interim fecal coliform standard

Output from the HSPF model was generated as an hourly timeseries and daily average timeseries of fecal coliform concentration at eight sub-watershed outlets, corresponding to the eight monitoring station locations, for Pigg River; and at two sub-watershed outlets, corresponding to the two monitoring station locations, for Old Womans Creek.

Observed data are collected through grab samples collected on (at best) a monthly basis. Because it is not practical to expect such data to exactly match an average simulated value on a specific day, other methods of comparison are needed. The strongest method of comparison is the use of the minimum and maximum simulated values – if we do an adequate job of simulation, then theoretically the observed data should fall roughly within the range of values simulated near the date of observed data collection. Other parameters to consider are violation rate, averages, medians, geometric means, etc., but the visual comparison provides the best picture of the simulation.

Calibration

The calibration period was roughly 1994-1998; the actual dates of the calibration period varied according to the period of record available during that time from each site (Table 5.10). Livestock numbers for the calibration period were different from existing conditions, and were assumed as described in Chapter 4. Pigg River was calibrated for water quality first; where applicable, the calibrated parameters were then used as initial estimates for the Old Womans Creek calibration.

Table 5.10. Calibration period for each water quality station.

Station ID	Calibration period
4ASDA000.67	n/a
4ASDA009.79	Feb 1994 – Oct 1998
4ASNW000.6	Jan 1994 – Oct 1998
4ACNT001.32	Jan 1997 – Oct 1998
4APGG003.29	Jan 1994 – Oct 1998
4APGG030.62	Jul 1994 – Oct 1998
4APGG052.73	Mar 1994 – Oct 1998
4APGG068.49	n/a
4AOWC002.35	n/a
4AOWC005.36	Mar 1994 – Dec 1998

n/a: no dates available from 1994-1998, station was not included in calibration step

Several input parameters were altered during calibration. The initial execution of the model for Pigg River showed very high bacteria concentrations watershed-wide. Additionally, an initial analysis of the breakdown of contributors to the bacteria concentration in the stream showed an unreasonably high contribution from livestock sources compared to BST data. The parameters adjusted to address these issues are listed in Table 5.11. It should be noted that the parameters altered in this table and the following paragraphs were those that held the most uncertainty in their initial estimation.

Table 5.11. Parameters altered during the Pigg River water quality calibration to fix high bacteria predictions.

Parameter	Adjustment
Wildlife time in streams	Decreased by a factor of 2 for Pigg River downstream of Rocky Mount and by a factor of 4 for tributaries to Pigg River and Pigg River above Rocky Mount
Cattle stream access	Decreased to 20% where DCR's database showed BMP implementation in Big Chestnut Creek; decreased to 75% for beef and 0% for dairy in subwatershed 22 where SWCD personnel were uncertain of dairy fencing
Interflow and Groundwater Concentrations	Halved watershed-wide
Cattle fecal coliform production	Decreased to fall within the range reported by ASAE (1998) and Geldreich (1978)

After decreasing the baseline predictions for fecal coliform, the peaks of simulation were not high enough. The peaks in simulation are driven by the amount of bacteria leaving the land surface. To address this, the washoff factor (WSQOP), which defines the amount of runoff needed to remove 90% of bacteria from the soil surface, was changed from 2.5 in/hr to 1.5 in/hr for residential areas and 2.0 in/hr for other pervious surfaces.

These alterations brought the upstream stations into an appropriate range, but the downstream stations were then being greatly underpredicted. Assuming that the downstream characterization is relatively accurate (there was much greater confidence in the downstream approximations, as they were in Pittsylvania County, where a higher level of detail was known about both human and livestock sources), this suggested that bacteria from upstream areas were dying off too fast and not reaching the downstream sections. As a result, the first-order decay rate in streams (FSTDEC) was changed from 1.15/day to 0.85/day for tributaries and 0.75/day for the larger portion of the Pigg downstream of Rocky Mount. Additionally, beef cows in Snow Creek were given full stream access to address a particularly low fecal coliform prediction in that watershed.

These changes produced an acceptable calibration for Pigg River (as shown in the following figures). The estimates for wildlife stream access, cattle bacteria production, WSQOP, and interflow and groundwater concentrations were used in the Old Womans Creek calibration. The initial estimate of FSTDEC (1.15/day) was used in Old Womans Creek. Additionally, 15 cows were added to sub-watershed 6 to occupy a pasture that was visible in aerial photographs but was not visible from the windshield survey of the watershed.

In Old Womans Creek, as often occurs in small upland watersheds, flows will drop to very low levels. At these low levels, HSPF has difficulty predicting bacteria concentrations and will predict unreasonably high values. Additionally, it is less likely that cattle will be wading and defecating in streams that fall to these low depths, as the benefits of stream wading are reduced. To help address this behavior and the limitation of the model, a 1-inch cutoff was instituted on cattle direct deposit. That is, when flow depths fall below one inch, cattle direct deposit contributions were set to zero. This is in accordance with the procedure initially outlined in the Mossy Creek and Long Glade Run TMDL (Benham et al., 2004) and subsequently used in the Beaver Creek and Mill Creek TMDLs (Benham et al., 2005a; Benham et al., 2005b).

After the modifications to input parameters made during the calibration, the observed and simulated data matched well. This can be seen in Figure 5.9, Figure 5.10, Figure 5.11, Figure 5.12, Figure 5.13, Figure 5.14, and Figure 5.15 .

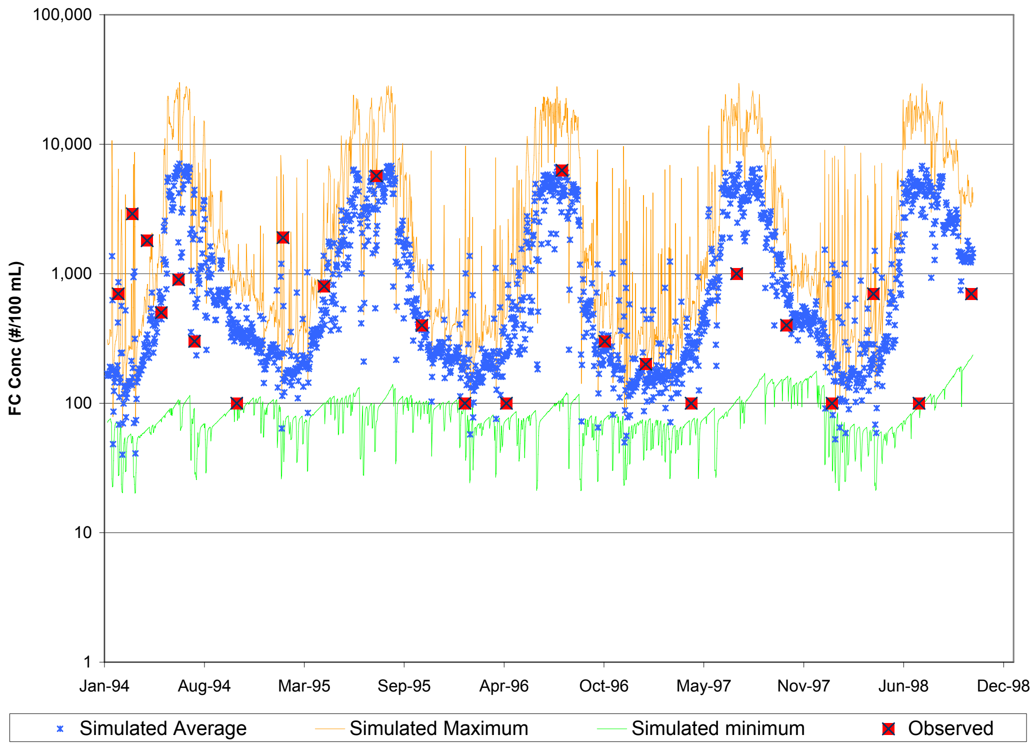

Figure 5.9. Observed water quality data at station 4ASDA009.79 plotted with the daily minimum, maximum, and average simulated values.

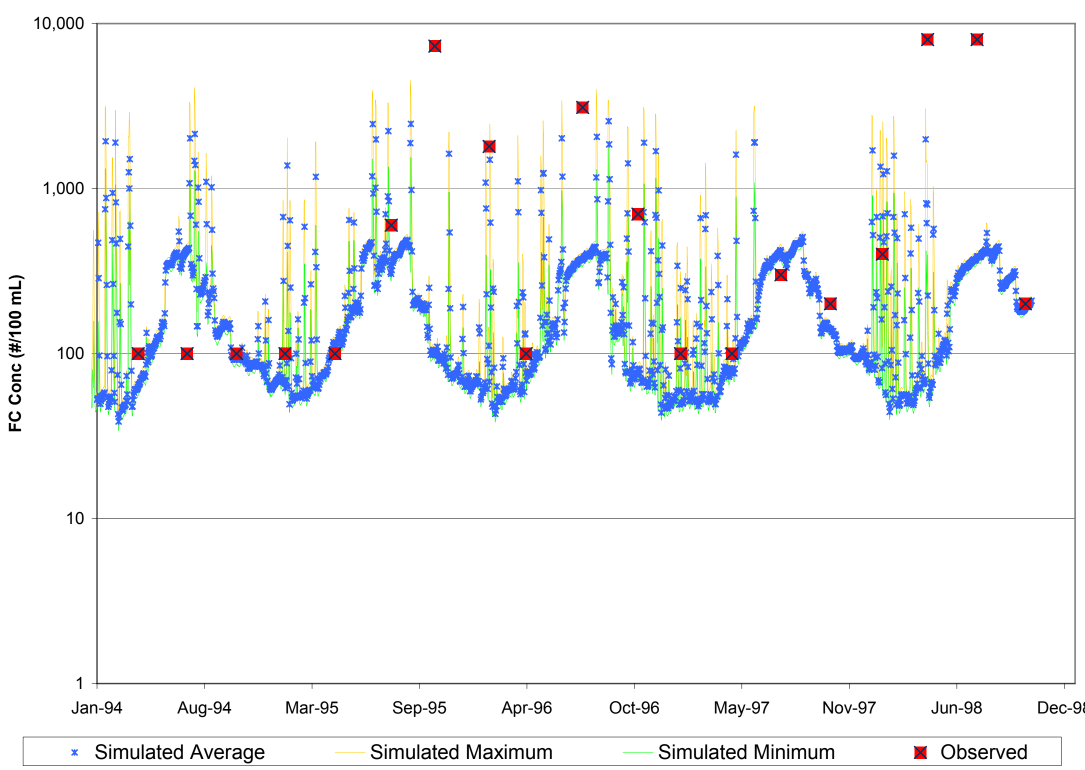

Figure 5.10. Observed water quality data at station 4ASNW000.60 plotted with the daily minimum, maximum, and average simulated values.

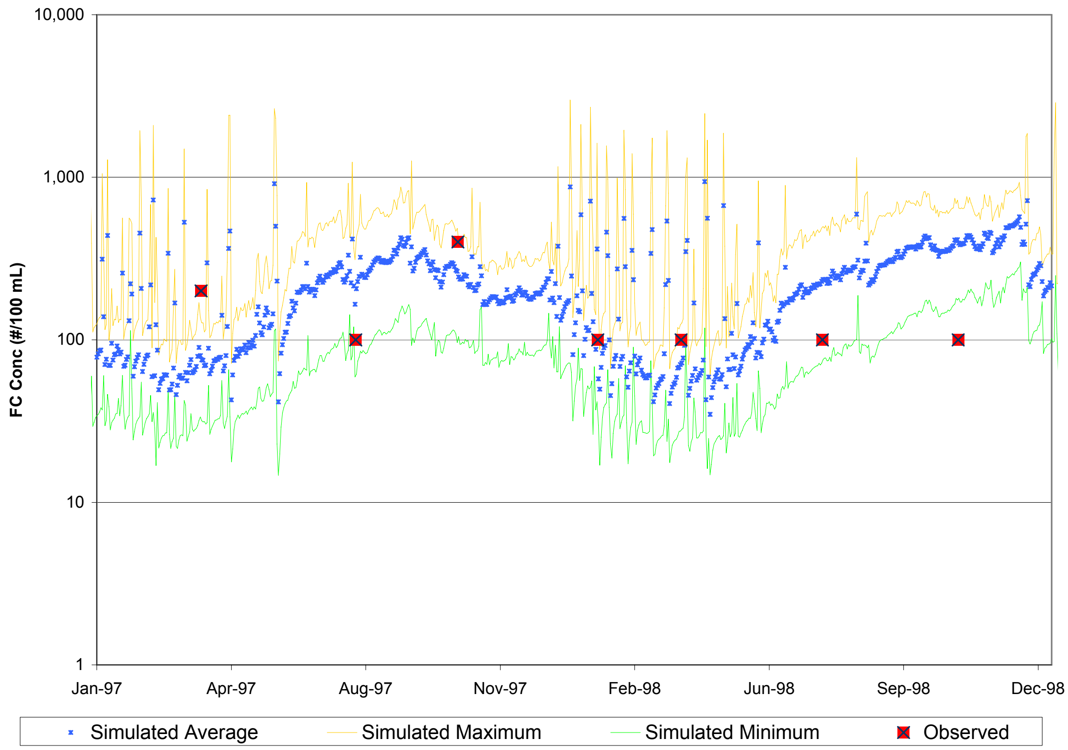

Figure 5.11. Observed water quality data at station 4ACNT001.32 plotted with the daily minimum, maximum, and average simulated values.

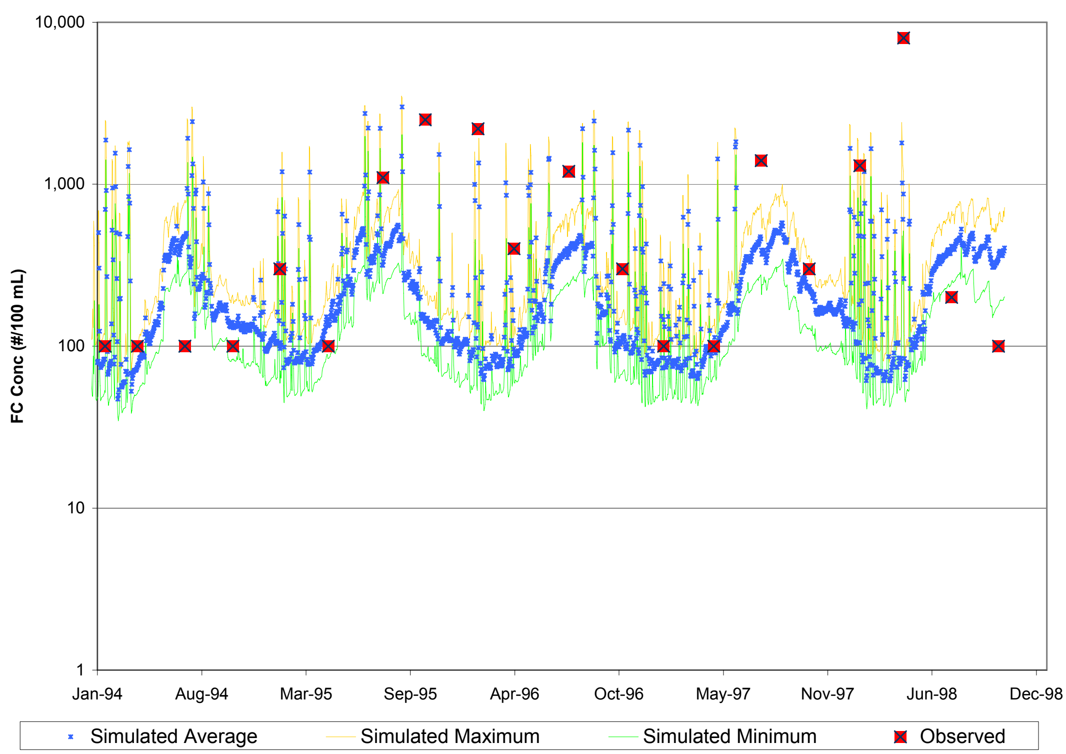

Figure 5.12. Observed water quality data at station 4APGG003.29 plotted with the daily minimum, maximum, and average simulated values.

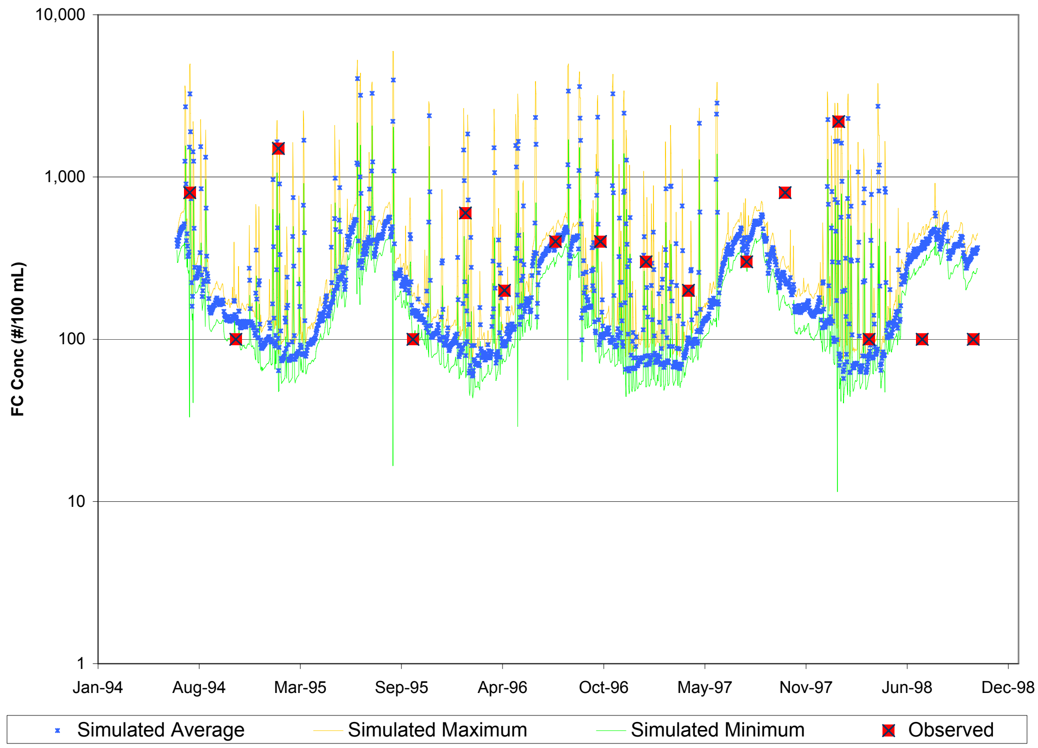

Figure 5.13. Observed water quality data at station 4APGG030.62 plotted with the daily minimum, maximum, and average simulated values.

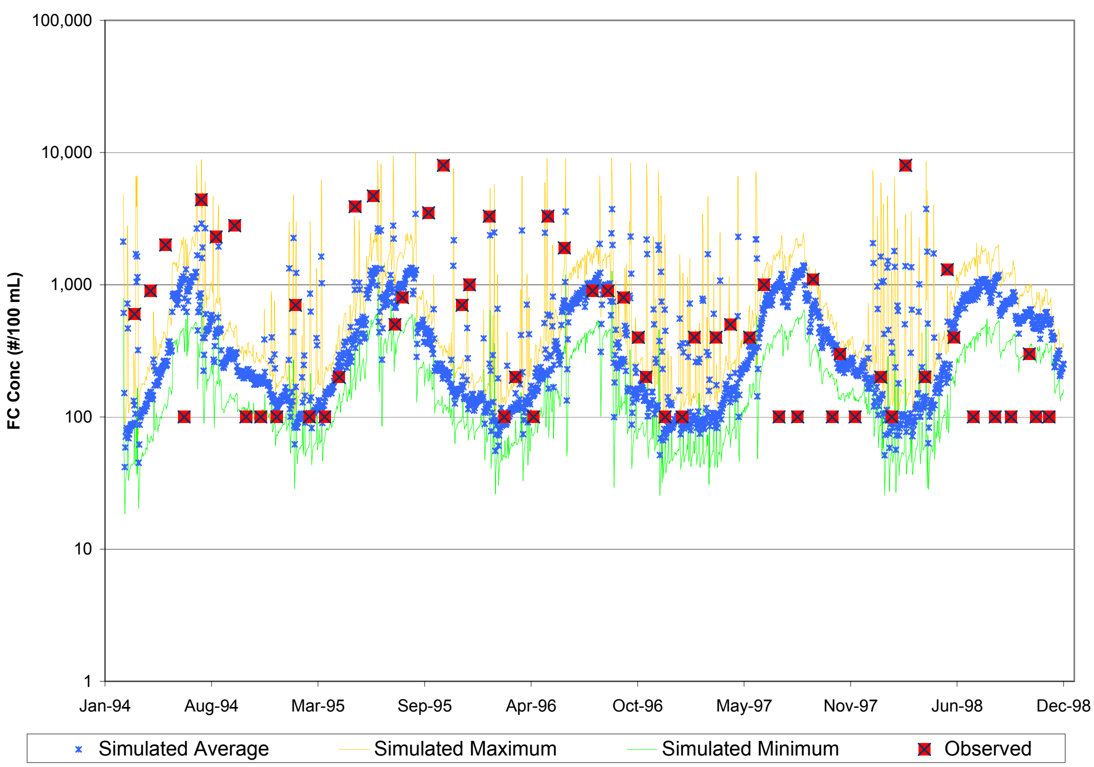

Figure 5.14. Observed water quality data at station 4APGG052.73 plotted with the daily minimum, maximum, and average simulated values.

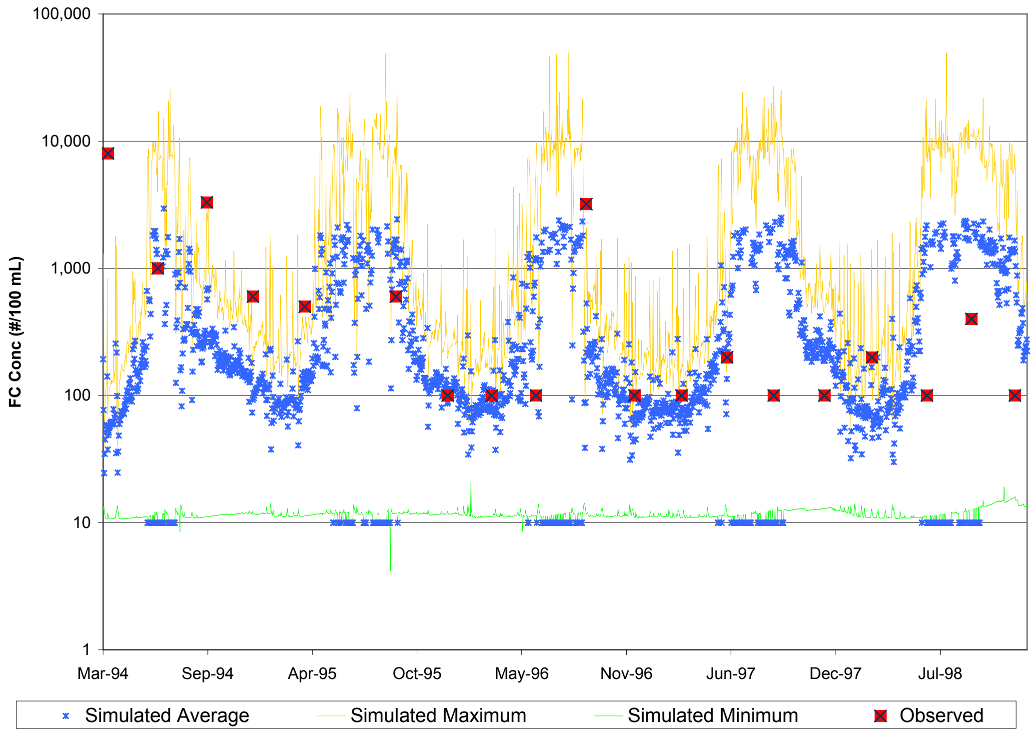

Figure 5.15. Observed data at station 4AOWC005.36 plotted with the daily minimum, maximum, and average simulated values.

Validation

The validation period was roughly 1999-2005; actual dates of validation varied according to the available records for the monitoring stations (Table 5.12).

Table 5.12. Validation period for each monitoring station.

Station ID	Validation Period
4ASDA000.67	Jul 2004 – Apr 2005
4ASDA009.79	Jan 1999 – Apr 2005
4ASNW000.6	Jan 1999 – Apr 2005
4ACNT001.32	Jan 1999 – May 2001
4APGG003.29	Jan 1999 – Apr 2005
4APGG030.62	Jan 1999 – Apr 2005
4APGG052.73	Jan 1999 – Apr 2005
4APGG068.49	Jul 2001 – Apr 2005
4AOWC002.35	Jul 2004 – Apr 2005
4AOWC005.36	Mar 1999 – Apr 2005

During the validation period, it was assumed that dairy farms in Pigg River that had been marked out of business in a file provided by Virginia Cooperative Extension were indeed out of business, as discussed in Chapter 4. Other parameters were held the same as the calibration period. Some key output parameters for the stations at the end of the impaired segments are presented in Table 5.13. The results of the validation are presented graphically in Figure 5.16, Figure 5.17, Figure 5.18, Figure 5.19, Figure 5.20, Figure 5.21, Figure 5.22, Figure 5.23, Figure 5.24, and Figure 5.25. The final calibrated water quality parameters are presented in Table 5.14.

Table 5.13. Statistics for the validation run.

Station ID	Impaired Segment	Observed		Simulated	
		Violation Rate	Geometric Mean (cfu/100 mL)*	Violation Rate	Geometric Mean (cfu/100 mL)†
4ASDA000.67	Story Creek	44%	399	33%	353
4ASNW000.6	Snow Creek	26%	236	23%	193
4APGG003.29	'Leesville Lake' – Pigg River	38%	266	32%	270
4APGG052.73	Upper Pigg River	38%	353	47%	432
4AOWC002.35	Old Womans Creek	22%	117	25%	172

*Geometric mean of all samples collected during the validation period
†Geometric mean of all simulated daily average values during the validation period

Table 5.14. Calibrated water quality parameters for Pigg River and Old Womans Creek.

Parameter	Definition	Units	FINAL CALIBRATION	FUNCTION OF…	Appendix E Table (if applicable)
PQUAL					
SQO	Initial storage of constituent	#/ac	0	Land use	
POTFW	Washoff potency factor	#/ton	0		
POTFS	Scour potency factor	#/ton	0		
ACQOP	Rate of accumulation of constituent	#/day	monthly[b]	Land use	5, 6
SQOLIM	Maximum accumulation of constituent	#	9 x ACQOP[b]	Land use	7, 8
WSQOP	Wash-off rate	in/hr	1.5 residential; 2.0 other	Land use	
IOQC	Constituent conc. in interflow	#/ft3	4248		
AOQC	Constituent conc. in active groundwater	#/ft3	2832		
IQUAL					
SQO	Initial storage of constituent	#/ac	$1x10^7$		
POTFW	Washoff potency factor	#/ton	0		
ACQOP	Rate of accumulation of constituent	#/day	$1x10^7$	Land use	
SQOLIM	Maximum accumulation of constituent	#	$3x10^7$	Land use	
WSQOP	Wash-off rate	in/hr	1.0	Land use	
GQUAL					
FSTDEC	First order decay rate of the constituent	1/day	1.15 OWC; 0.85 small PGG; 0.75 large PGG		
THFST	Temperature correction coeff. for FSTDEC		1.05		

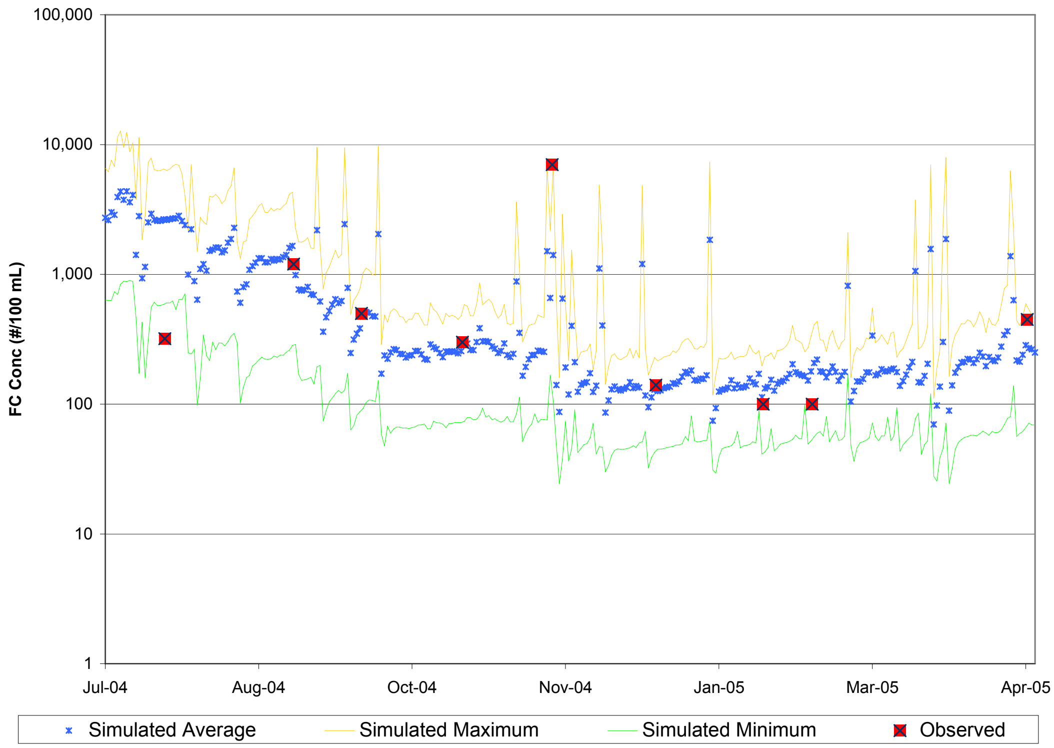

Figure 5.16. Observed water quality data at station 4ASDA000.67 plotted with the daily minimum, maximum, and average simulated values during the validation period.

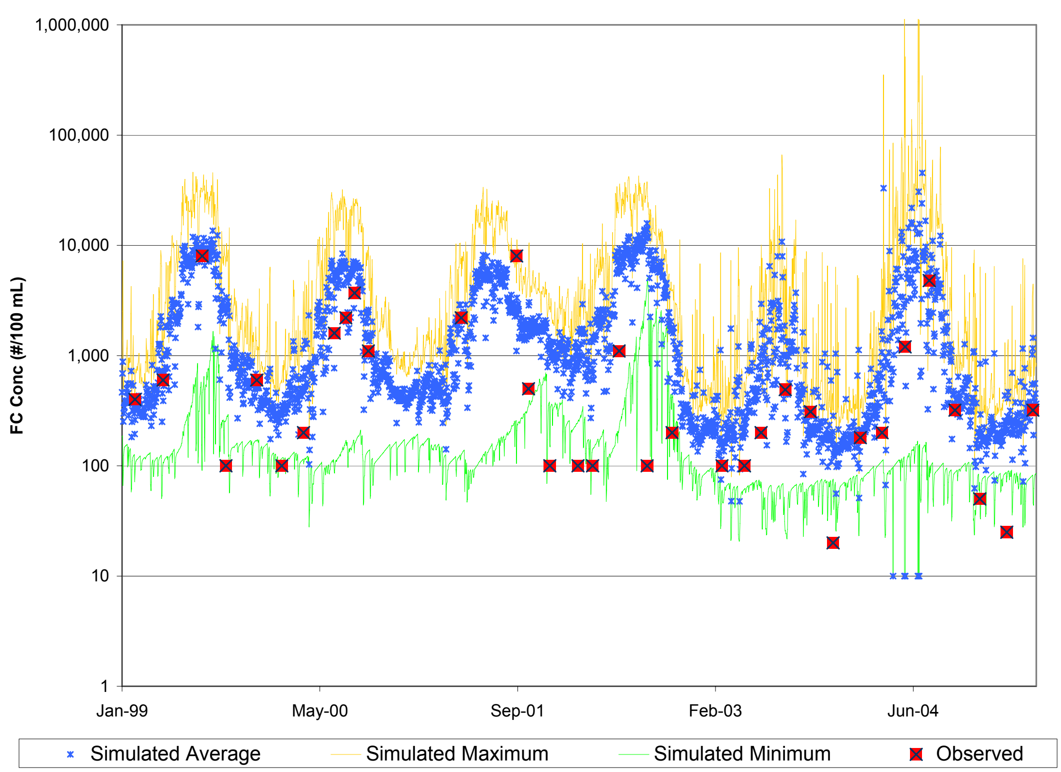

Figure 5.17. Observed water quality data at station 4ASDA009.79 plotted with the daily minimum, maximum, and average simulated values for the validation period.

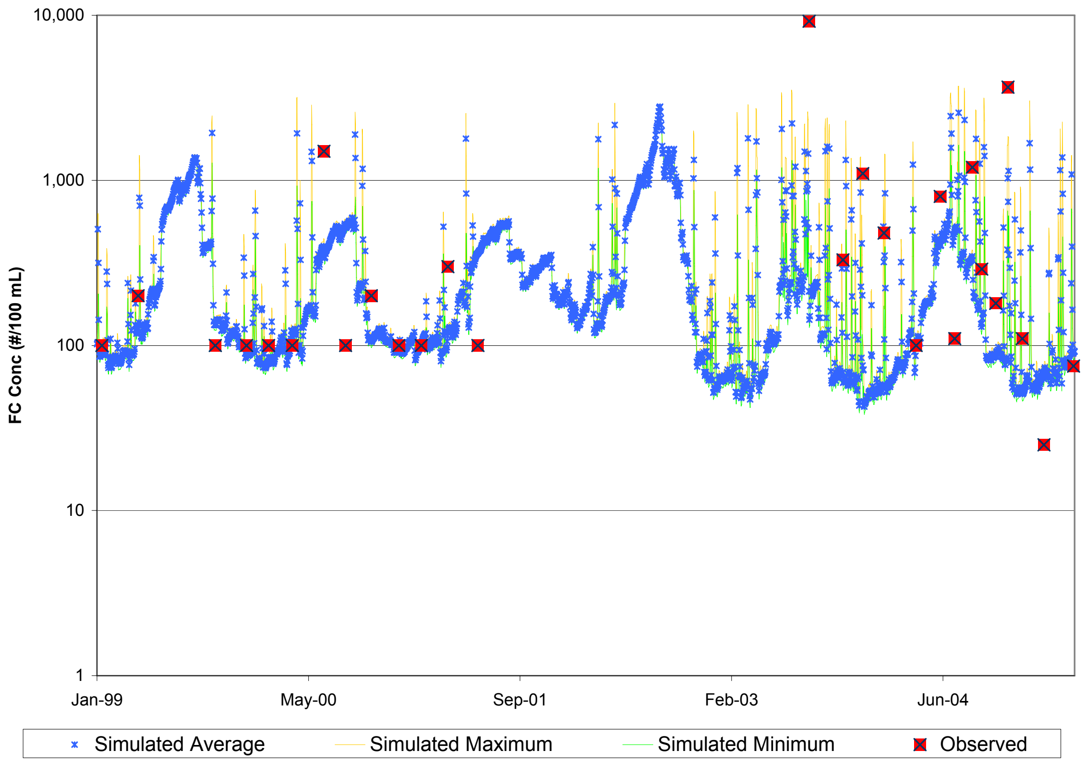

Figure 5.18. Observed water quality data at station 4ASNW000.60 plotted with the daily minimum, maximum, and average simulated values during the validation period.

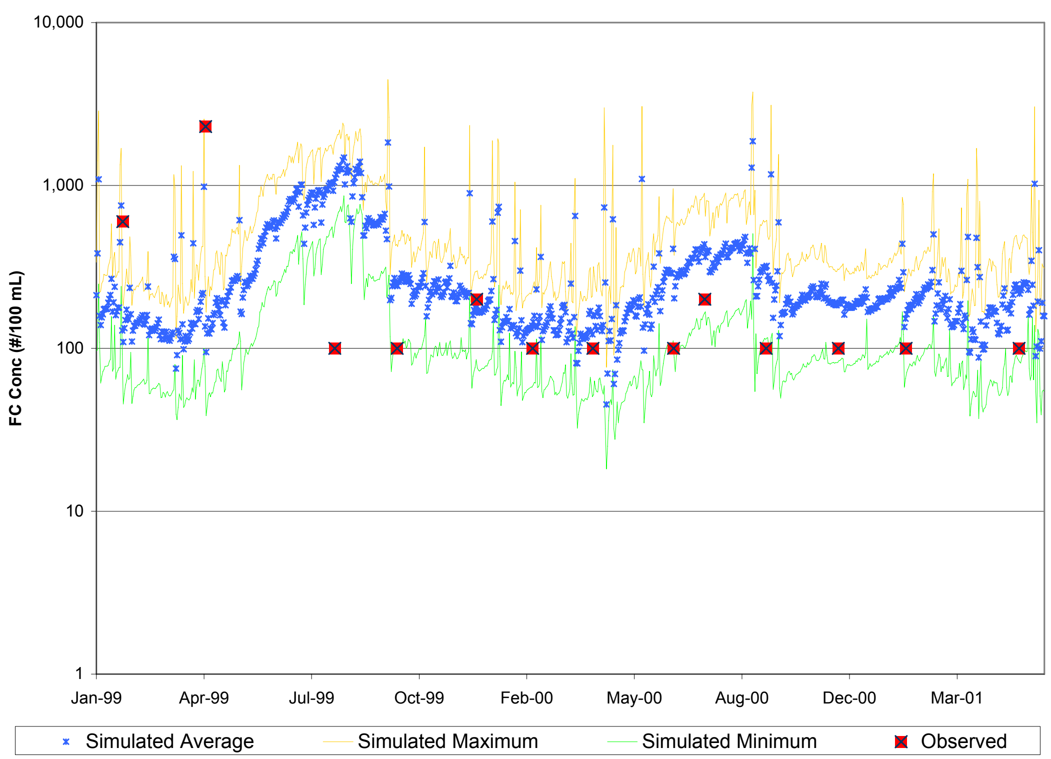

Figure 5.19. Observed water quality data at station 4ACNT001.32 plotted with the daily minimum, maximum, and average simulated values during the validation period.

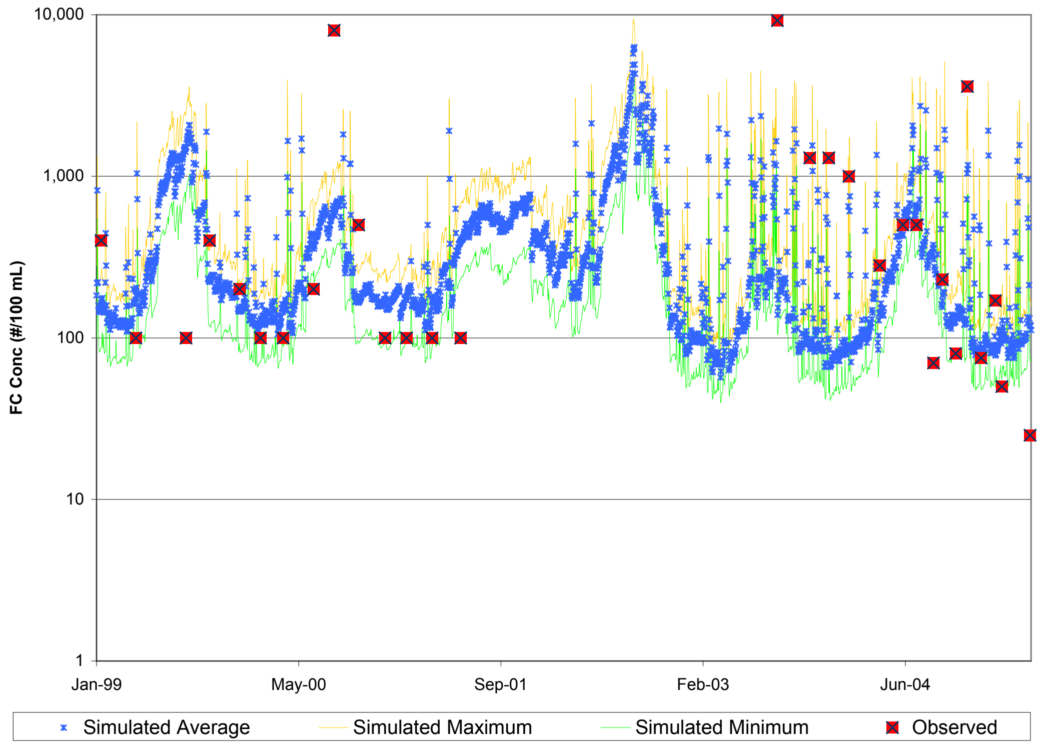

Figure 5.20. Observed water quality data at station 4APGG003.29 plotted with the daily minimum, maximum, and average simulated values during the validation period.

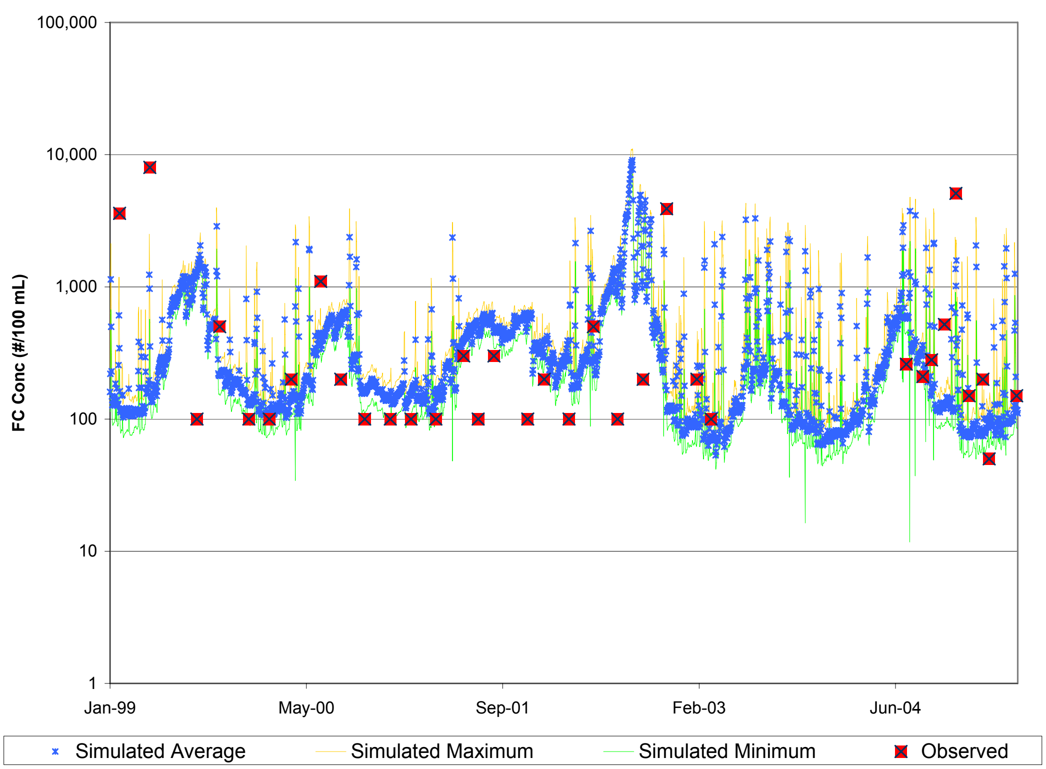

Figure 5.21. Observed water quality data at station 4APGG030.62 plotted with the daily minimum, maximum, and average simulated values.

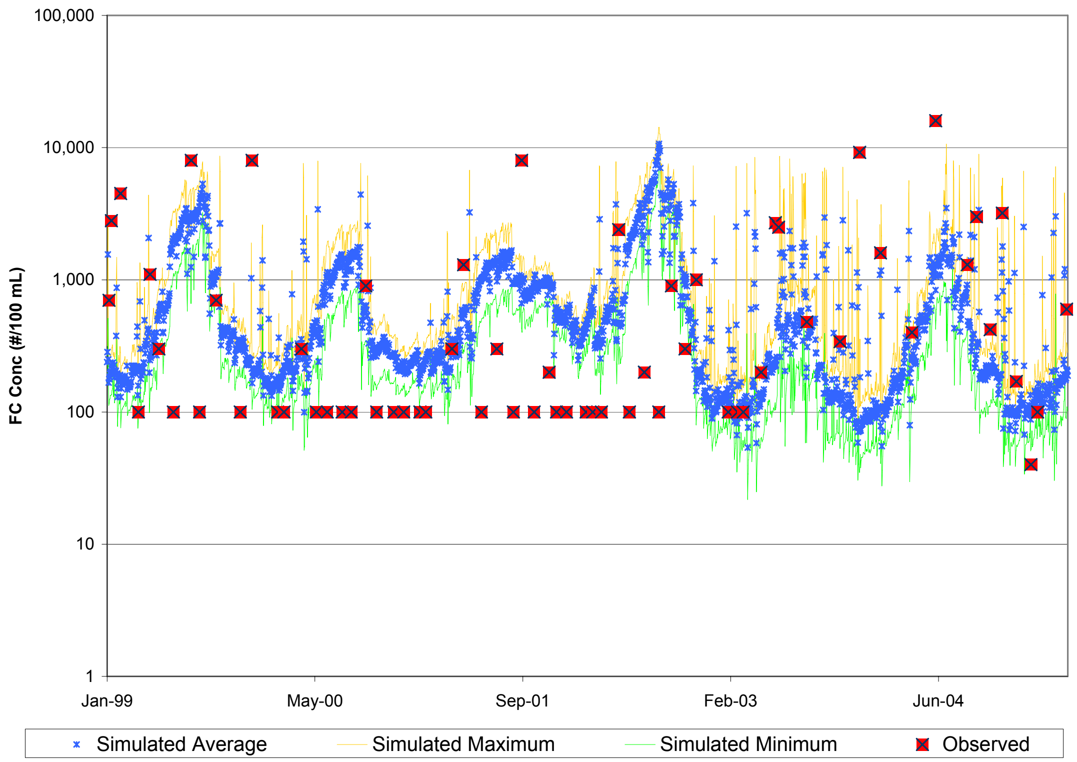

Figure 5.22. Observed water quality data at station 4APGG052.73 plotted with the daily minimum, maximum, and average simulated values during the validation period.

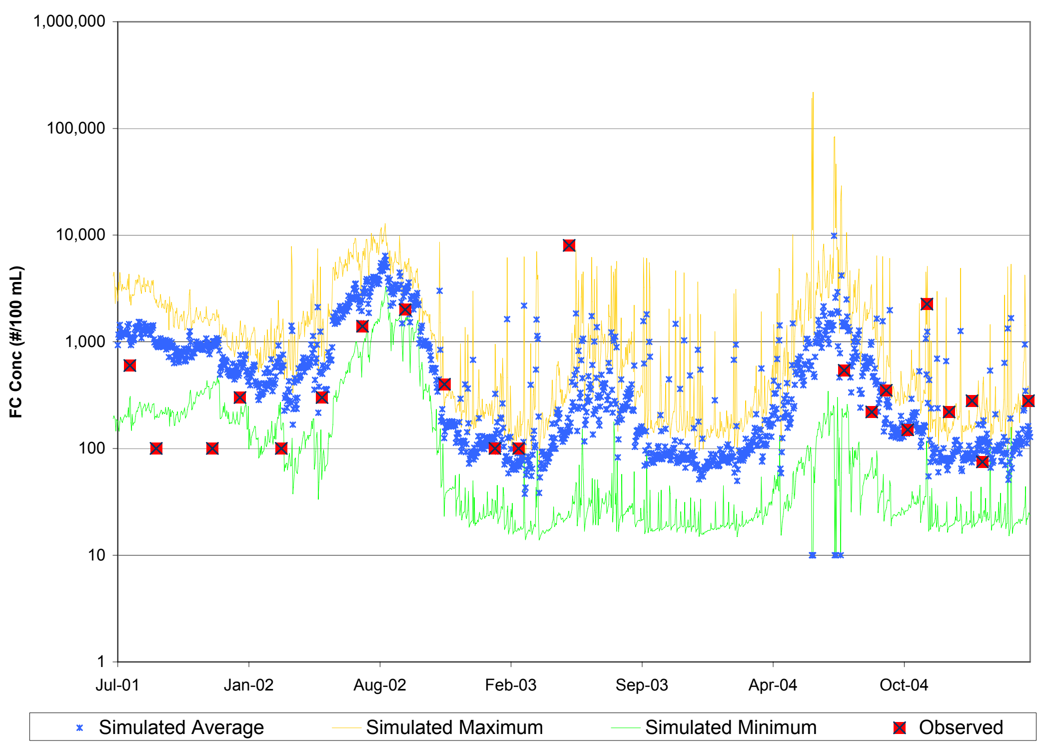

Figure 5.23. Observed water quality data at station 4APGG068.49 plotted with the daily minimum, maximum, and average simulated values during the validation period.

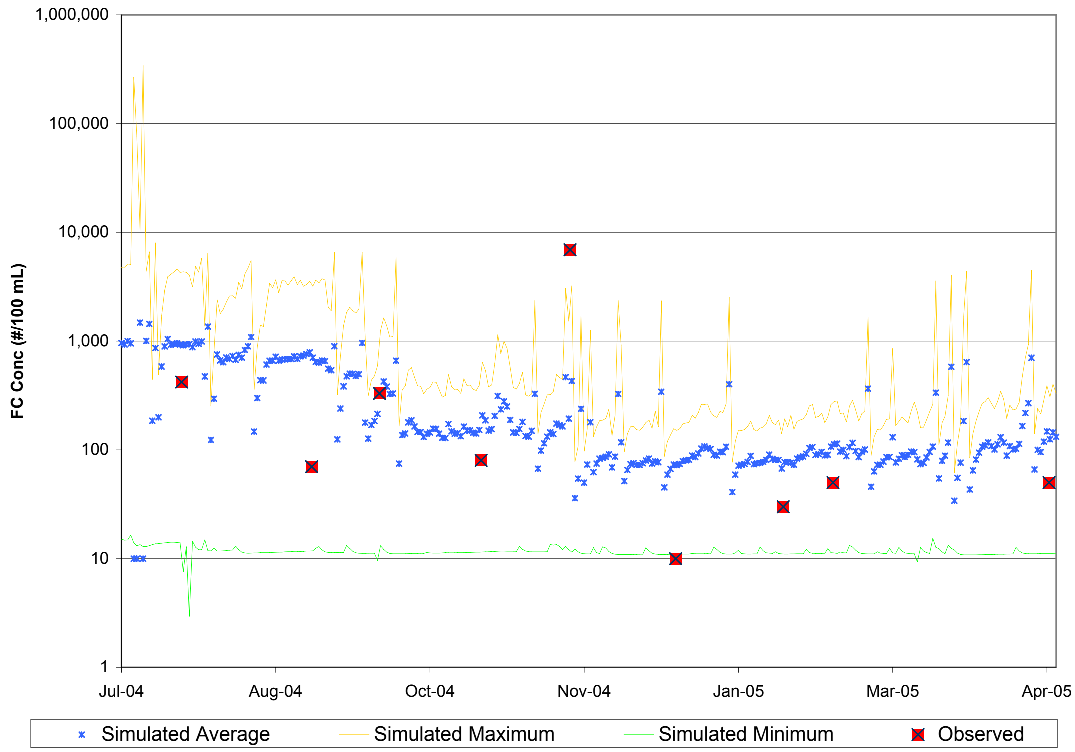

Figure 5.24. Observed bacteria data at station 4AOWC002.35 plotted with the daily minimum, maximum, and average simulated values during the validation period.

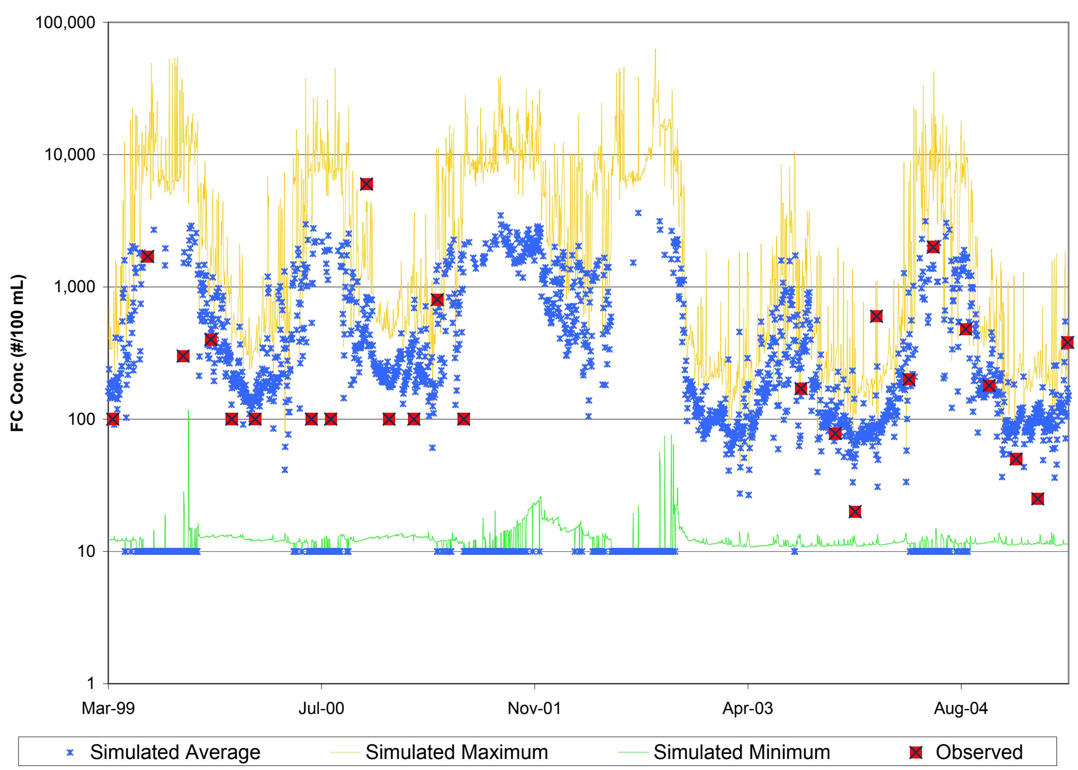

Figure 5.25. Observed bacteria data at station 4AOWC005.36 plotted with the daily minimum, maximum, and average simulated values during the validation period.

BST Comparison

Bacterial Source Tracking (BST) data were collected from July 2004-June 2005 at six stations in the Pigg River basin: 4ASDA000.67, 4ASNW000.60, 4APGG003.29, 4APGG030.62, 4APGG052.73, and 4APGG068.49. BST data were collected during the same time period at one station in Old Womans Creek: 4AOWC002.35. BST data were analyzed using the Antibiotic Resistance Analysis method (Harwood et al., 2003; Stoeckel et al., 2004; Hagedorn, 2006). BST results are reported as a flow- and concentration- weighted average of the twelve samples. This means that the percent contribution from each source for each observation is multiplied by the flow rate and total *E. coli* concentration on the day of sample collection; then, this weighted product is summed for each source category for all observation dates; finally, the summed weighted product for each source category is divided by the sum of weighted products for all source categories and all observation dates. For comparison, model outputs from different sources were generated for July 2004-June 2005 and were also flow- and concentration- weighted in the same manner. The BST results for each station are presented in Table 5.15, along with the simulated breakdown of source contributors. The minimum and maximum observed and simulated values are also presented in this table.

It is difficult to draw exact conclusions from a BST analysis. The observed BST clearly show that, at all Pigg River stations, livestock are the primary contributors to the bacteria concentrations in the river. Wildlife come in as a clear second place. This trend is reflected in the simulated data. The modeled data also show a higher human and pet signature downstream of Rocky Mount; a trend that seems logical but that is not reflected in the observed data. In Old Womans Creek, livestock and wildlife are the most significant contributors to the in-stream bacteria concentrations; this trend is reflected in the simulated data.

The ranges of data (both simulated and observed) are evidence that the breakdown of sources will vary considerably according to the time and location a sample is collected. This variance is largely dependent on the time since the last storm event – the relative contributions from sources at high flows are not the same as those at low flows. The flow- and concentration- weighting method used by DEQ and thus used in analysis of the simulated data gives higher weight to samples taken at higher flows and concentrations – i.e., those more likely to correspond to a recent storm event. This puts more weight on the overland sources of bacteria and less on the in-stream sources of bacteria. As an additional complicating factor, pet and human bacteria sources are often difficult to distinguish in BST analysis, which means that the actual breakdown between the two might not be the same as that presented in Table 5.15.

Overall, the simulated relative signatures of humans and pets, livestock, and wildlife are reasonably close to the observed values and support the calibration and validation of Pigg River and Old Womans Creek.

Table 5.15. Bacterial Source Breakdown - Percent Contributions.

Station ID	Observed/ Simulated	Livestock (Min; Max)	Wildlife (Min; Max)	Human (Min; Max)	Pet (Min; Max)
4ASDA000.67	Observed	**52** (25; 71)	**32** (8; 67)	**2** (0; 4)	**15** (0; 46)
	Simulated	**69** (0.1; 87)	**11** (0.1; 47)	**15** (0; 39)	**4** (0; 11)
4ASNW000.6	Observed	**41** (0; 71)	**29** (0; 67)	**5** (0; 50)	**26** (0; 63)
	Simulated	**79** (0.2; 88)	**13** (0.1; 57)	**6** (0; 11)	**2** (0; 4)
4APGG003.29	Observed	**58** (4; 79)	**23** (14; 92)	**6** (0; 25)	**14** (0; 46)
	Simulated	**71** (0.1; 84)	**16** (0.2; 76)	**9** (0; 20)	**3** (0; 9)
4APGG030.62	Observed	**48** (0; 71)	**45** (25; 100)	**1** (0; 8)	**7** (0; 59)
	Simulated	**68** (0.1; 80)	**13** (0.2; 70)	**13** (0; 29)	**5** (0; 13)
4APGG052.73	Observed	**73** (12; 92)	**19** (0; 42)	**2** (0; 12)	**6** (0; 67)
	Simulated	**71** (0.1; 87)	**10** (0.1; 53)	**13** (0; 30)	**6** (0; 18)
4APGG068.49	Observed	**57** (29; 96)	**22** (0; 55)	**6** (0; 17)	**14** (0; 46)
	Simulated	**69** (0; 86)	**20** (0.1; 70)	**7** (0; 23)	**2** (0; 8)
4AOWC002.35	Observed	**36** (8; 83)	**38** (0; 90)	**1** (0; 50)	**25** (0; 59)
	Simulated	**56** (0; 83)	**34** (0.1; 86)	**4** (0; 24)	**2** (0; 13)

Chapter 6: TMDL Allocations

The objective of a TMDL is to allocate allowable loads among different pollutant sources so that the appropriate control actions can be taken to achieve water quality standards (USEPA, 1991).

6.1. Background

The objective of the bacteria TMDLs for Pigg River, Snow Creek, Story Creek, and Old Womans Creek was to determine what reductions in fecal coliform and *E. coli* loadings from point and nonpoint sources are required to meet state water quality standards. The state water quality standards for *E. coli* used in the development of the TMDLs were 126 cfu/100 mL (calendar-month geometric mean) and 235 cfu/100 mL (single sample maximum). The TMDLs consider all significant sources contributing bacteria and *E. coli* to the impaired streams. The sources can be separated into nonpoint and point sources. The different sources in the TMDL are defined in the following equation:

$$TMDL = WLA + LA + MOS \qquad [6.1]$$

Where: WLA = waste load allocation (point source contributions)
LA = load allocation (nonpoint source contributions); and
MOS = margin of safety.

An implicit MOS was used in these bacteria TMDLs by using conservative estimations of all factors that would affect bacteria loadings in the watershed (e.g., animal numbers, production rates, contributions to the stream). These factors were estimated in such a way as to represent the worst-case scenario; i.e., they describe the worst stream conditions that could exist in the watersheds. Creating TMDLs with conservative estimates ensures that the worst-case scenario has been considered and that no water quality standard violations will occur if the TMDL plan is followed.

A translator equation developed by VADEQ (equation 6.2) was used to convert the fecal coliform model output to *E. coli* for comparison with the water quality standards. The *E. coli* translator equation was implemented in the HSPF simulation using the GENER block. In order to develop the actual TMDL equation, it was necessary to generate *loads* (rather than concentrations) of *E. coli*. Daily *E. coli* loads were obtained by using the *E. coli* concentrations calculated from the translator equation and multiplying them by the average daily flow. Annual loads were obtained by summing the daily loads and dividing by the number of years in the allocation period.

$$\log_2 EC(cfu/100mL) = -0.0172 + 0.91905 * \log_2 FC(cfu/100mL) \qquad [6.2]$$

When developing a bacteria TMDL, the required bacteria load reductions are modeled by decreasing the amount of bacteria applied to the land surface; these reductions are presented in the tables in the following sections. In the model, this has the effect of reducing the amount of bacteria that reaches the stream, which is the ultimate goal of the TMDL. Thus, the reductions called for in the following sections indicate the need to decrease the amount of bacteria reaching the stream in order to meet the applicable water quality standard. The reductions shown in these sections are not intended to infer that agricultural producers should reduce their herd size, or limit the use of manures as fertilizer or soil conditioner. Rather, it is assumed that the required reductions from affected agricultural source categories (cattle direct deposit, cropland, etc.) will be accomplished by implementing BMPs like filter strips, stream fencing, and off-stream watering; and that required reductions from residential source categories will be accomplished by repairing aging septic systems, eliminating straight pipe discharges, and other appropriate measures included in the TMDL Implementation Plan.

A period of five years was used for source allocations. Observed meteorological data from the Rocky Mount weather station were extracted for the period 1994-1998 and used in the allocation. This period was selected because it incorporates average rainfall, low rainfall, and high rainfall years; and the climate during this period caused a wide range of hydrologic events including both low and high flow conditions. The bacteria loading in the model for allocation scenarios was representative of future conditions.

The calendar-month geometric mean values used in this report are geometric means of the simulated daily concentrations. Because HSPF was operated with a one-hour time step in this study, 24 hourly concentrations were generated each day. To estimate the calendar-month geometric mean from the hourly HSPF output, we took the arithmetic mean of the hourly values on a daily basis, and then calculated the geometric mean from these average daily values.

6.2. Future Conditions

To ensure that the developed TMDL will be applicable in the future, expected urban development in the Franklin County portion of the Pigg River watershed was considered during allocation. Information on expected urban development in Pittsylvania County was not available at the time of this study. A future land use map from the Franklin County Comprehensive Plan currently under development was consulted to determine what changes might be expected in the future. As can be seen from Figure 6.1, most development is expected to occur along the corridor between Rocky Mount and Ferrum. For purposes of TMDL modeling, conservation area land uses were not altered from current conditions; low density residential, medium density residential, and growth areas were classified as low density residential (LDR); and industrial centers were classified as high density residential (HDR). Table 6.1 summarizes the change in land use as a result of future conditions. These changes, as well as the population changes described in Chapter 4 for future conditions, were made prior to generation of allocation scenarios for Pigg River, Snow Creek, and Story Creek.

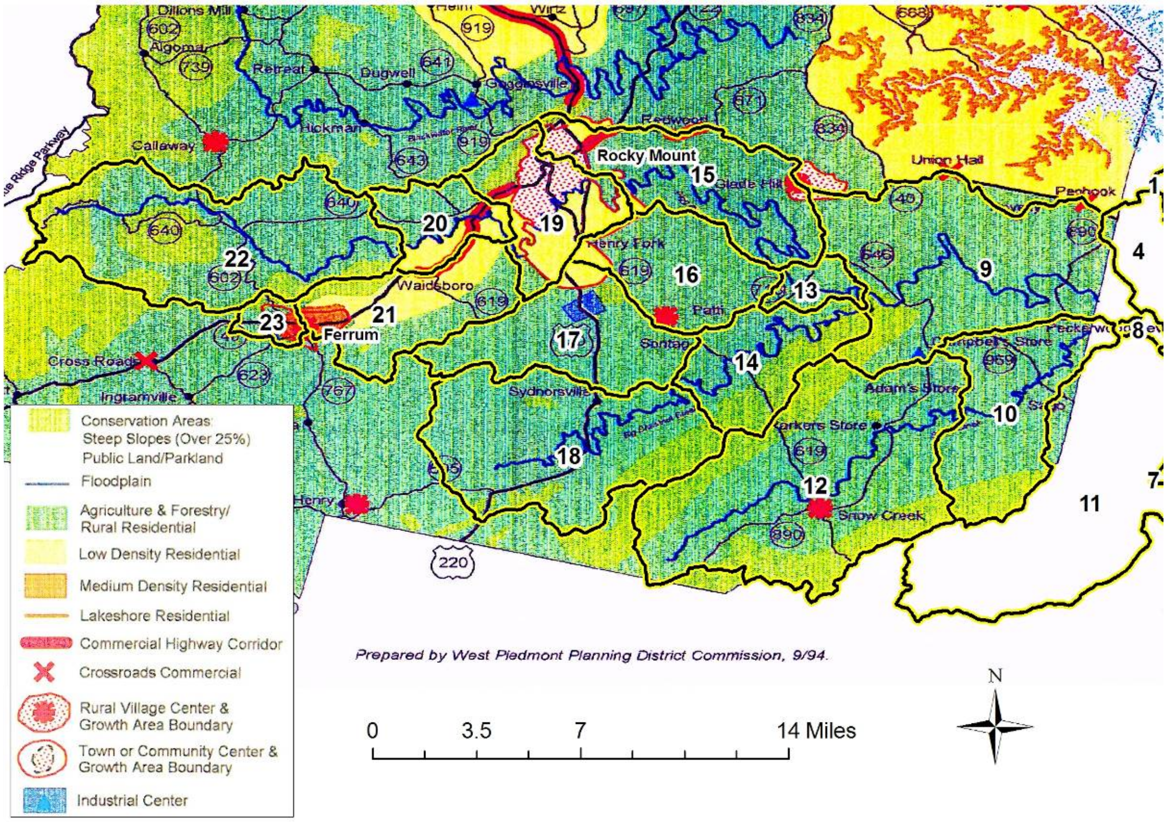

Figure 6.1. Projected future land use in the Pigg River area of Franklin County. Courtesy of Franklin County Planning & Community Development Department.

Table 6.1. Transfer of area from existing land use categories to future land use categories in Pigg River.

Sub-watershed	Future Land Use	Existing Conditions Land Use acres (%)*		
		Cropland	Forest	Pasture
9	HDR	1 (0.2%)	155 (0.9%)	32 (0.7%)
12†	HDR	0 (0%)	2 (0%)	4 (0%)
	LDR	7 (0.7%)	169 (0.9%)	66 (0.8%)
15	LDR	9 (2.3%)	629 (8.6%)	242 (6.1%)
16	LDR	29 (8.8%)	502 (9.9%)	236 (6.6%)
17	HDR	0 (0.1%)	316 (3.8%)	138 (5.2%)
	LDR	21 (10.1%)	281 (3.4%)	174 (6.6%)
19	LDR	49 (88.5%)	3,459 (63.9%)	1,210 (83%)
20	LDR	51 (40.8%)	1,217 (39.4%)	661 (42.6%)
21‡	LDR	148 (80.1%)	2,869 (37.5%)	1,315 (70.2%)
22	LDR	0 (0.1%)	44 (0.2%)	6 (0.2%)
23‡	LDR	3 (28.4%)	193 (17.3%)	73 (29.7%)

*Percent is the percent the recategorized area is of the total existing area of the land use in each sub-watershed

†Sub-watershed is in Snow Creek

‡Sub-watersheds comprise Story Creek

6.3. Snow Creek Bacteria TMDL

6.3.1. Existing Conditions

Analysis of the simulation results for the existing conditions in the watershed (Table 6.2) shows that contributions from cattle direct deposits are the primary source of *E. coli* to the stream. Contributions from pervious land surfaces and wildlife direct deposits are also significant contributors to the mean daily *E. coli* concentration. The results in this table were taken as the average daily contributions for the allocation simulation period, irrespective of the magnitude of the concentration or the flow rate (factors that were considered in the earlier section detailing the source breakdown used in the calibration). Table 6.2 gives an idea of what sources will be the dominant contributors to the instantaneous *E. coli* concentrations, and thus what sources will control the violations of the single sample standard.

Table 6.2. Relative contributions of different *E. coli* sources to the overall *E. coli* concentration for existing conditions in the Snow Creek watershed.

Source	Mean Daily *E. coli* Concentration by Source, cfu/100 mL	Relative Contribution by Source
All Sources	135	
Nonpoint source loadings from pervious land segments	42	31%
Direct nonpoint source loadings to the stream from wildlife	24	18%
Direct nonpoint source loadings to the stream from livestock	63	47%
Interflow and groundwater contribution	3	2%
Straight-pipe discharges to stream	1	1%
Nonpoint source loadings from impervious land use	0.1	<1%

The contribution of each of the sources listed in Table 6.2 to the calendar-month geometric mean *E. coli* concentration is shown in Figure 6.2. The pervious land surface (PLS) category in Figure 6.2 includes both the 'nonpoint source loadings from pervious land segments' and the 'interflow and groundwater contribution' categories from Table 6.2. Because contributions from impervious surfaces only occur during rainfall events, there are many days with zero concentration from impervious areas; therefore, the calendar month geometric mean of impervious contributions is zero and does not appear in Figure 6.2.

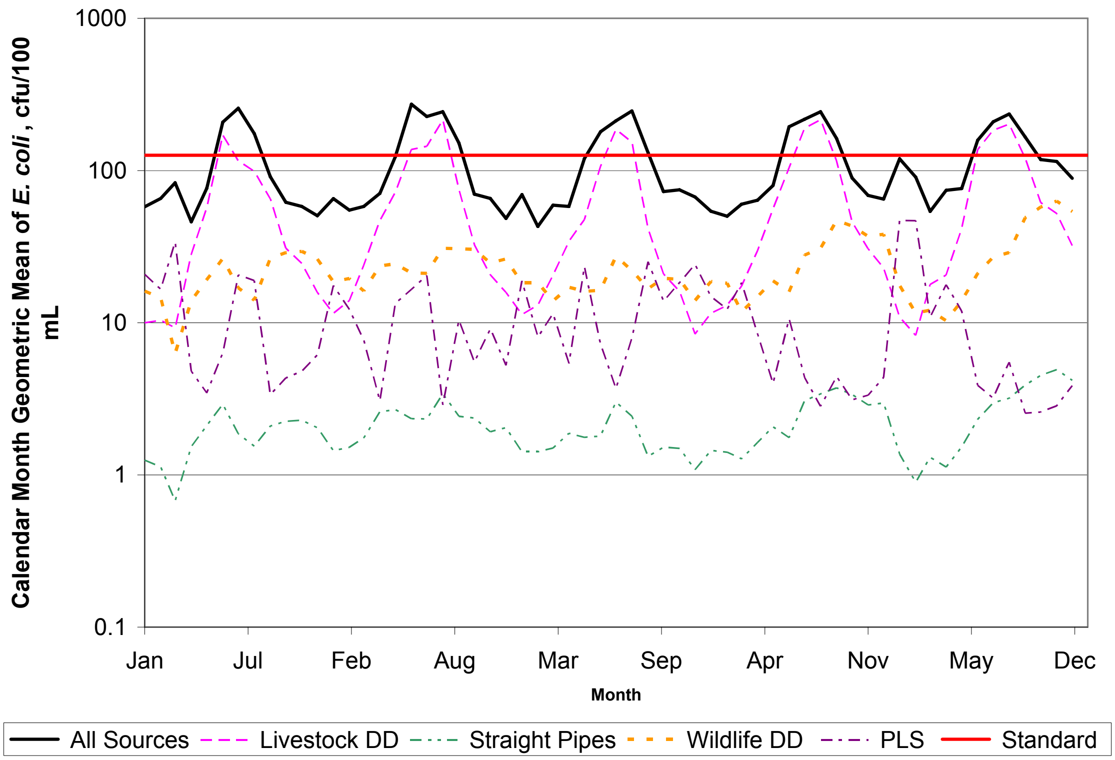

Figure 6.2. Contributions of different sources to the calendar-month geometric mean *E. coli* concentration at the outlet of Snow Creek for existing conditions.

The contributions from livestock direct deposit dominate the calendar-month geometric mean concentration. The cyclic nature of livestock direct deposit contributions is due to increased time spent in streams by livestock during summer months, combined with lower flow volumes; these two factors combine to increase bacteria concentrations during the summer months. Wildlife direct deposits and contributions from pervious land surfaces are also significant to the calendar-month geometric mean concentration in Snow Creek. From this graph, it is evident that violations of the calendar-month geometric mean standard will be most controlled by contributions from livestock direct deposit, and further that it will be impossible to meet the calendar-month geometric mean standard without reducing livestock direct deposit contributions.

6.3.2. Allocation Scenarios

A variety of allocation scenarios were evaluated to meet the *E. coli* TMDL goal of a calendar-month geometric mean concentration less than 126 cfu/100 mL and a single-sample maximum concentration of less than 235 cfu/100 mL. The scenarios and results are summarized in Table 6.3; recall that these reductions are those used for modeling, and implementation of these reductions will require implementation of BMPs as discussed at the beginning of this chapter. One successful scenario was found to meet the standards for Snow Creek.

Table 6.3. Bacteria allocation scenarios for the Snow Creek watershed.

Scenario Number	Required Fecal Coliform Loading Reductions to Meet the *E. coli* Standards, %						% Violation of *E. coli* Standard	
	Live-stock DD*	Loads from Cropland	Loads from Pasture	Wildlife DD*	Straight Pipes	Loads from Residential	Geomean	Single Sample
Unsuccessful Scenarios								
Baseline Future Conditions	0	0	0	0	0	0	32	11
1	30	0	0	0	100	0	27	7
2	100	0	90	0	100	90	0	0.2
3	60	0	95	0	100	90	0	0.05
Successful Scenario								
4	60	0	95	0	100	95	0	0

*DD = direct deposit

Table 6.3 includes two categories of scenarios: those that were successful and those that were unsuccessful. Presentation of the unsuccessful scenarios illustrates the need for the reductions called for in the successful scenarios. Unsuccessful scenario 01 shows, as supported by Figure 6.2, that large reductions from livestock direct deposit are needed in order to bring the geometric mean concentrations into compliance. The reductions in livestock direct deposits have a noticeable effect on the single sample standard violations as well; however, even 100% livestock exclusion is not sufficient, even coupled with 90% reductions from the major overland contributors (pasture and residential), to meet the single sample standard. Scenario 03 shows that 95%

reductions from both major overland categories are needed to comply with the instantaneous standard. This scenario also shows that a 60% reduction in livestock direct deposits to the stream is sufficient to ensure compliance with the calendar month geometric mean standard. As can be seen from Figure 6.3, this brings the simulated geometric mean concentrations very close to the standard, and a lower reduction would not meet the standard. Figure 6.3 displays the simulated daily average and calendar-month geometric mean concentrations at the Snow Creek outlet, along with the two *E. coli* standards.

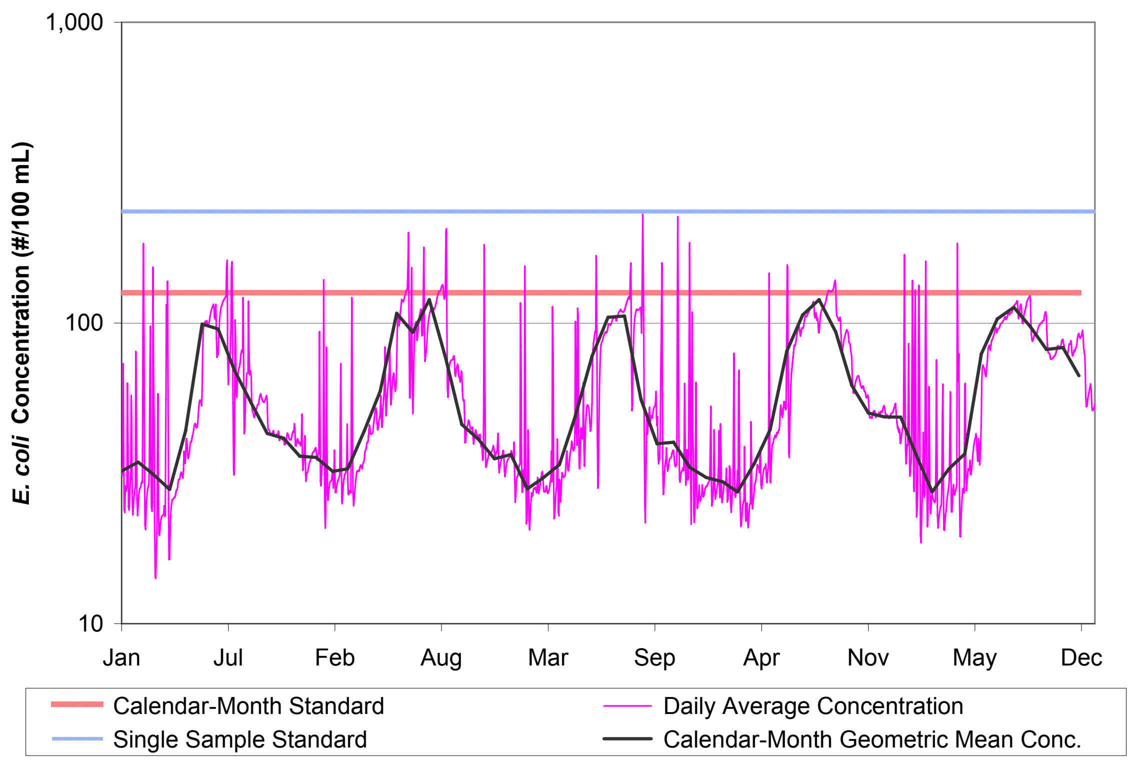

Figure 6.3. Simulated *E. coli* concentrations for the successful allocation scenario (04) for Snow Creek.

Loadings for the existing conditions, baseline future conditions, and the successful TMDL allocation scenario (04) are presented for nonpoint sources by land use in Table 6.4 and for direct nonpoint sources in Table 6.5.

Table 6.4. Annual nonpoint source fecal coliform loads under existing and future conditions and corresponding reductions for TMDL allocation scenario 04 for Snow Creek.

Land use category	Existing Conditions: Existing Conditions Load ($x10^{12}$ cfu/yr)	Existing Conditions: Percent of total land deposited load from nonpoint sources	Future Conditions: Future Conditions Load ($x10^{12}$ cfu/yr)	Future Conditions: Percent of total land deposited load from nonpoint sources	Allocation Scenario: TMDL nonpoint source allocation load ($x10^{12}$ cfu/yr)	Allocation Scenario: Percent Reduction from Future Load
Cropland	231	2%	231	2%	231	0%
Pasture	12,691	84%	12,691	83%	635	95%
Residential*	818	5%	854	6%	43	95%
Forest	1,439	9%	1,439	9%	1,439	0%
Total	15,179		15,215		2,347	85%

*Includes loads applied to pervious areas of both High and Low Density Residential

Table 6.5. Annual direct nonpoint source fecal coliform loads under existing and future conditions and corresponding reductions for TMDL allocation scenario 04 for Snow Creek.

Source	Existing Conditions: Existing Conditions Load ($x10^{12}$ cfu/yr)	Existing Conditions: Percent of total direct deposited load from direct nonpoint source	Future Conditions: Future Conditions Load ($x10^{12}$ cfu/yr)	Future Conditions: Percent of total direct deposited load from direct nonpoint source	Allocation Scenario: TMDL direct nonpoint source allocation load ($x10^{12}$ cfu/yr)	Allocation Scenario: Percent Reduction from Future Load
Livestock in Streams	206	72%	206	72%	82	60%
Straight Pipes	5	2%	5	2%	0	100%
Wildlife in Streams	75	26%	75	26%	75	0%
Total	286		286		157	45%

The fecal coliform loads presented in Table 6.4 and Table 6.5 are the fecal coliform loads that result in in-stream *E. coli* concentrations that meet the applicable *E. coli* water quality standards after application of the VADEQ fecal coliform to *E. coli* translator to the HSPF-predicted mean daily fecal coliform concentrations.

6.3.3. Waste Load Allocation

There are currently no permitted facilities in the Snow Creek watershed. However, to account for future growth in the area, a waste load allocation of <1% of the TMDL was modeled for Snow Creek.

6.3.4. Summary of Snow Creek's TMDL Allocation Scenario for Bacteria

A TMDL for *E. coli* has been developed for Snow Creek. The TMDL addresses the following issues:

1. The TMDL meets both the calendar-month geometric mean and single sample water quality standards.
2. Because *E. coli* loading data were not available to quantify nonpoint source bacterial loads, available fecal coliform loading data were used as input to HSPF. HSPF was then used to simulate in-stream fecal coliform concentrations. The VADEQ fecal coliform to *E. coli* concentration translator equation was then used to convert the simulated fecal coliform concentrations to *E. coli* concentrations.
3. The TMDL was developed taking into account all fecal bacteria sources (anthropogenic and natural) from both point and nonpoint sources.
4. An implicit margin of safety (MOS) was incorporated by utilizing professional judgment and conservative estimates of model parameters.
5. Both high- and low-flow stream conditions were considered while developing the TMDL. In the Snow Creek watershed, low stream flow was found to be the environmental condition most likely to cause a violation of the geometric mean criterion; high stream flow conditions after storm events were most likely to cause violations of the single sample criterion; because the TMDL was developed using a continuous simulation model, it applies to both high- and low-flow conditions.

6. Both the flow regime and bacteria loading to Snow Creek are seasonal. The TMDL accounts for these seasonal effects.

The selected *E. coli* TMDL allocation that meets both *E. coli* criteria requires a 60% reduction in cattle direct deposits to the stream; 100% reduction in straight pipe contributions; and 95% reduction from pasture and residential surfaces. Using equation 6.1, the summary of the bacteria TMDL for Snow Creek for the selected allocation scenario (04) is given in Table 6.6.

Table 6.6. Annual *E. coli* loadings (cfu/year) at the watershed outlet used for the Snow Creek bacteria TMDL.

Parameter	ΣWLA	ΣLA	MOS*	TMDL
E. coli	<1%	8.47×10^{13}	--	8.60×10^{13}

*Implicit MOS

6.4. Story Creek Bacteria TMDL

6.4.1. Existing Conditions

Analysis of the simulation results for the existing conditions in the watershed (Table 6.7) shows that contributions from livestock direct deposit dominate the in-stream concentrations of *E. coli*. Contributions from pervious land surfaces and wildlife direct deposits constitute a noticeable portion of the average daily *E. coli* concentration. The results in this table were taken as the average daily contributions for the allocation simulation period, irrespective of the magnitude of the concentration or the flow rate (factors that were considered in the earlier section detailing the source breakdown used in the calibration). Table 6.7 gives an idea of what sources will be the dominant contributors to the instantaneous *E. coli* concentrations, and thus what sources will control the violations of the single sample standard.

Table 6.7. Relative contributions of different *E. coli* sources to the overall *E. coli* concentration for existing conditions in the Story Creek watershed.

Source	Mean Daily *E. coli* Concentration by Source, cfu/100 mL	Relative Contribution by Source
All Sources	341	
Nonpoint source loadings from pervious land segments	34	10%
Direct nonpoint source loadings to the stream from wildlife	61	18%
Direct nonpoint source loadings to the stream from livestock	222	65%
Interflow and groundwater contribution	7	2%
Straight-pipe discharges to stream	18	5%
Nonpoint source loadings from impervious land use	0.3	<1%
Point sources*	5.75	2%

*Contributions from point sources assumed to be discharging at their permitted limits

The contribution of each of the sources listed in Table 6.7 to the calendar-month geometric mean *E. coli* concentration is shown in Figure 6.4. The 'PLS' category in Figure 6.4 includes both the 'nonpoint source loadings from pervious land segments' and the 'interflow and groundwater contribution' categories from Table 6.7. Because contributions from impervious surfaces only occur during rainfall events, there are many days with zero concentration from impervious areas; therefore, the calendar month geometric mean of impervious contributions is zero and does not appear in Figure 6.4.

The contributions from livestock direct deposit also dominate the calendar-month geometric mean concentration. The cyclic nature of livestock direct deposit contributions is due to increased time spent in streams by livestock during summer months, combined with lower flow volumes; these two factors combine to increase bacteria concentrations during the summer months. Wildlife direct deposits are also significant to the calendar-month geometric mean concentration in Story Creek. Pervious land surfaces and straight pipes make about an equal contribution to the concentrations. From this graph, it is evident that violations of the calendar-month geometric mean standard will be most controlled by contributions from livestock direct deposit, and further that it will be impossible to meet the calendar-month geometric mean standard without reducing livestock direct deposit contributions. The last few months on the graph, where the dotted orange line representing wildlife direct deposits crosses the standard, show that it will be impossible to meet the calendar-month geometric mean standard without reducing wildlife direct deposit contributions.

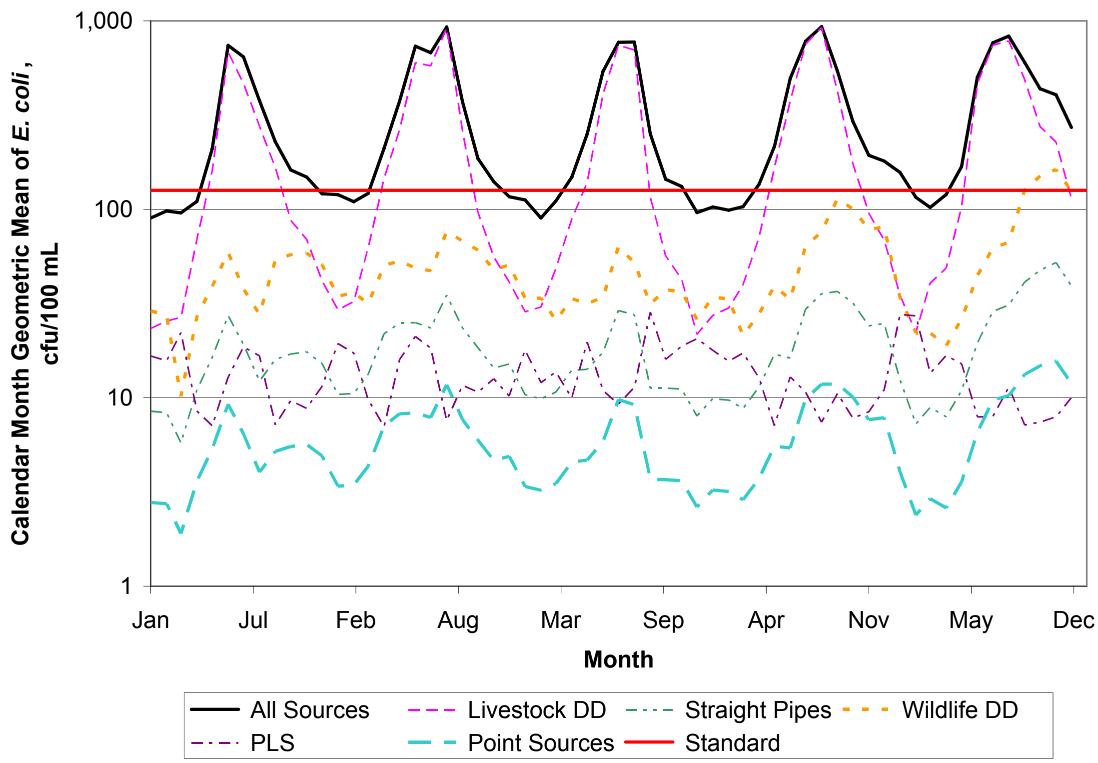

Figure 6.4. Contributions of different sources to the calendar-month geometric mean *E. coli* concentration at the outlet of Story Creek for existing conditions.

6.4.2. Allocation Scenarios

A variety of allocation scenarios were evaluated to meet the *E. coli* TMDL goal of a calendar-month geometric mean concentration less than 126 cfu/100 mL and a single-sample maximum concentration of less than 235 cfu/100 mL. The scenarios and results are summarized in Table 6.7; recall that these reductions are those used for modeling, and implementation of these reductions will require implementation of BMPs as discussed at the beginning of this chapter. Two successful scenarios were found to meet the standards for Story Creek.

Table 6.8. Bacteria allocation scenarios for the Story Creek watershed.

Scenario Number	Required Fecal Coliform Loading Reductions to Meet the *E. coli* Standards, %						% Violation of *E. coli* Standard	
	Live-stock DD*	Loads from Cropland	Loads from Pasture	Wildlife DD*	Straight Pipes	Loads from Residential	Geomean	Single Sample
Unsuccessful Scenarios								
Baseline Future Conditions	0	0	0	0	0	0	68	45
1	100	100	100	0	100	100	10	1
2	100	100	100	40	100	100	2	0
3	100	0	80	45	100	80	0	0.05
Successful Scenarios								
4	100	100	100	45	100	100	0	0
5	100	0	85	45	100	75	0	0

*DD = direct deposit

Table 6.8 includes two categories of scenarios: those that were successful and those that were unsuccessful. Presentation of the unsuccessful scenarios illustrates the need for the reductions called for in the successful scenarios. Unsuccessful scenario 01 shows, as supported by Figure 6.4, that eliminating all anthropogenic sources of bacteria in the watershed will not bring Story Creek into compliance with either *E. coli* standard. Scenario 02 demonstrates that even a 40% reduction in wildlife direct deposits is not sufficient to meet the calendar-month geometric mean standard. Successful scenario 04 shows the minimum wildlife direct deposit reductions needed to bring the watershed into compliance with the calendar-month geometric mean standard, with all anthropogenic sources eliminated.

As a general rule, direct deposit sources (wildlife, livestock, and straight pipes) control violations of the calendar-month geometric mean standard. These three sources control the constant inputs to the water body, and thus control the geometric mean of the daily average predictions over the entire month. Overland sources (runoff from pasture, cropland, forest, and residential areas) are generally more important to the violations of the single sample standard, as these sources control the large spikes in bacteria concentration predictions that occur after storm events. Given these general rules, and knowing that the calendar-month standard was the controlling factor dictating the reductions called for in Table 6.8, it was hypothesized that lower reductions could be called for from overland sources without requiring additional reductions from wildlife direct deposits. For scenarios 03 and 05, the wildlife direct deposit reductions were held constant at the minimum value to achieve standards compliance determined from scenarios 02 and 04. Reductions called for from overland sources were then altered. In this way, relatively minor contributors to the bacteria load (e.g., cropland, see later in this section) were not called to a 100% reduction. Unsuccessful scenario 03 demonstrates that cropland sources do not contribute a significant amount to the violations of either standard, and that high reductions are still needed from pasture and residential sources. Successful scenario 05 requires a larger reduction from the primary source of overland bacteria loading (pasture), and a significant reduction from the next major source of bacteria (residential). Although not explicitly modeled in this study, concerns have been raised regarding the potential for leaking sewer lines in the Story Creek area of the watershed; these should be addressed while addressing residential sources during implementation. Because scenario 05 is a more equitable and achievable scenario, it has been chosen for summary in the rest of this section. Either scenario 04 or 05 could be chosen as the successful scenario by the stakeholder committee. Figure 6.5 displays the simulated daily average and calendar-month geometric mean concentrations at the Story Creek outlet for scenario 05, along with the two *E. coli* standards.

Loadings for the existing conditions, baseline future conditions, and the successful TMDL allocation scenario (05) are presented for nonpoint sources by land use in Table 6.9 and for direct nonpoint sources in Table 6.10. The fecal coliform loads presented in these tables are the fecal coliform loads that result in in-stream *E. coli* concentrations that meet the applicable *E. coli* water quality standards after application of the VADEQ fecal coliform to *E. coli* translator to the HSPF-predicted mean daily fecal coliform concentrations.

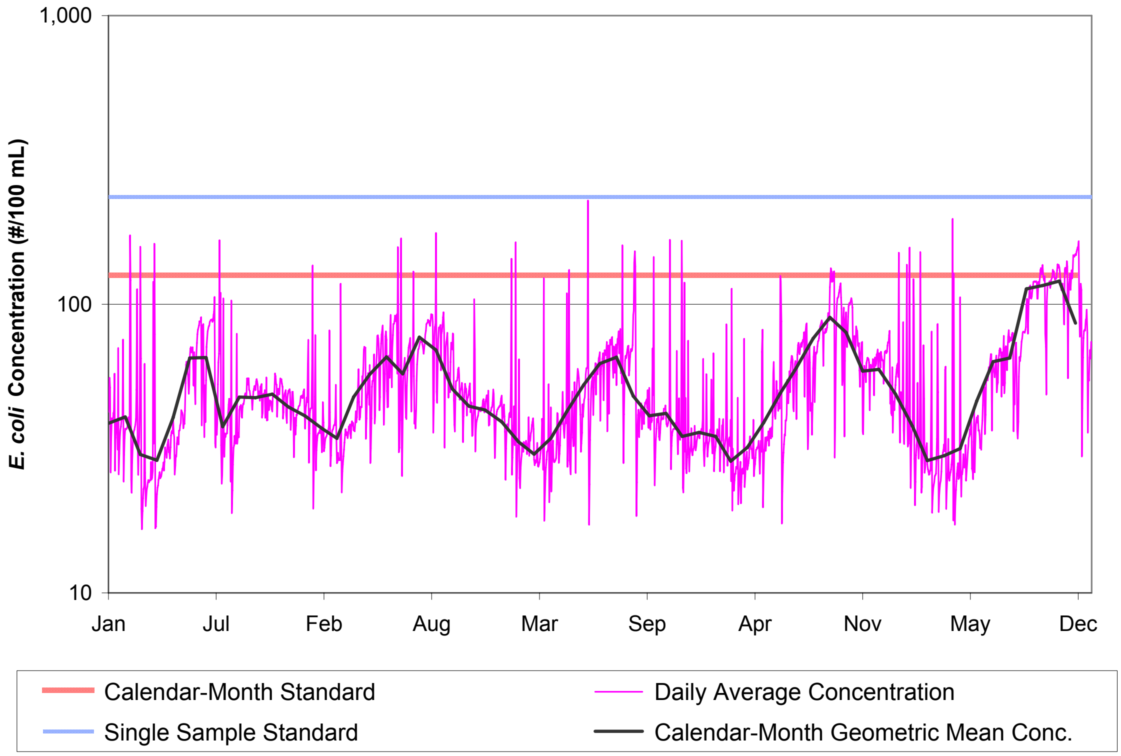

Figure 6.5. Simulated *E. coli* concentrations for the successful allocation scenario (05) for Story Creek.

Table 6.9. Annual nonpoint source fecal coliform loads under existing and future conditions and corresponding reductions for TMDL allocation scenario 05 for Story Creek.

	Existing Conditions		Future Conditions		Allocation Scenario	
Land use category	**Existing Conditions Load ($x10^{12}$ cfu/yr)**	**Percent of total land deposited load from nonpoint sources**	**Future Conditions Load ($x10^{12}$ cfu/yr)**	**Percent of total land deposited load from nonpoint sources**	**TMDL nonpoint source allocation load ($x10^{12}$ cfu/yr)**	**Percent Reduction from Future Load**
Cropland	26	1%	9	0%	9	0
Pasture	2,816	77%	2,826	77%	424	85%
Residential*	570	16%	588	16%	147	75%
Forest	240	7%	247	7%	247	0
Total	3,652		3,670		827	77%

*Includes loads applied to pervious areas of both High and Low Density Residential

Table 6.10. Annual direct nonpoint source fecal coliform loads under existing and future conditions and corresponding reductions for TMDL allocation scenario 05 for Story Creek.

Source	Existing Conditions		Future Conditions		Allocation Scenario	
	Existing Conditions Load ($x10^{12}$ cfu/yr)	Percent of total direct deposited load from direct nonpoint source	Future Conditions Load ($x10^{12}$ cfu/yr)	Percent of total direct deposited load from direct nonpoint source	TMDL direct nonpoint source allocation load ($x10^{12}$ cfu/yr)	Percent Reduction from Future Load
Livestock in Streams	40	71%	40	14%	0	100%
Straight Pipes	4	7%	4	1%	0	100%
Wildlife in Streams	12	21%	12	4%	7	45%
Total	56		56		7	88%

6.4.3. Waste Load Allocation

A waste load allocation (WLA) was assigned to the one permitted point source facility in the Story Creek watershed (Table 6.11). The point source was represented in the allocation scenario by its current permit conditions; no reductions were required from the point source in the TMDL. Current permit requirements are expected to result in attainment of the *E. coli* WLA as required by the TMDL. Point source contributions to bacteria concentrations, even in terms of maximum flow, are minimal. In addition, the point source facility is required to discharge at or below the bacteria water quality criteria and therefore cannot cause a violation of those criteria without also violating the discharge permit. Because the permit for this facility already protects against violating the bacteria water quality standard, there is no need to modify the existing permit.

Table 6.11. Point source discharging into the Story Creek watershed.

Permit Number	Facility Name	Flow (gpd)	Permitted *E. coli* Conc. (cfu/100 mL)	Permitted *E. coli* Load (cfu/yr)	Allocated *E. coli* Load (cfu/yr)
VA0029254	Ferrum Town - STP	4×10^5	126	6.99×10^{11}	6.99×10^{11}

6.4.4. Summary of Story Creek's TMDL Allocation Scenario for Bacteria

A TMDL for *E. coli* has been developed for Story Creek. The TMDL addresses the following issues:

1. The TMDL meets both the calendar-month geometric mean and single sample water quality standards.
2. Because *E. coli* loading data were not available to quantify nonpoint source bacterial loads, available fecal coliform loading data were used as input to HSPF. HSPF was then used to simulate in-stream fecal coliform concentrations. The VADEQ fecal coliform to *E. coli* concentration translator equation was then used to convert the simulated fecal coliform concentrations to *E. coli* concentrations.
3. The TMDL was developed taking into account all fecal bacteria sources (anthropogenic and natural) from both point and nonpoint sources.
4. An implicit margin of safety (MOS) was incorporated by utilizing professional judgment and conservative estimates of model parameters.
5. Both high- and low-flow stream conditions were considered while developing the TMDL. In the Story Creek watershed, low stream flow was found to be the environmental condition most likely to cause a violation of the geometric mean criterion; high stream flow conditions after storm events were most likely to cause violations of the single sample criterion; because the TMDL was developed using a continuous simulation model, it applies to both high- and low-flow conditions.
6. Both the flow regime and bacteria loading to Story Creek are seasonal. The TMDL accounts for these seasonal effects.

The selected *E. coli* TMDL allocation that meets both *E. coli* criteria requires a 100% reduction in cattle direct deposits to the stream; 100% reduction in straight pipe contributions; 45% reduction in wildlife direct deposits to the stream; 85% reduction from pasture areas; and 75% reduction from residential surfaces. Using equation 6.1, the summary of the bacteria TMDL for Story Creek for the selected allocation scenario (05) is given in Table 6.12.

Table 6.12. Annual *E. coli* loadings (cfu/yr) at the watershed outlet used for the Story Creek bacteria TMDL.

Parameter	ΣWLA	ΣLA	MOS*	TMDL
E. coli	6.99×10^{11} *(VA0029254 = 6.99×10^{11})*	1.86×10^{13}	--	1.93×10^{13}

*Implicit MOS

6.5. Upper Pigg River Bacteria TMDL

6.5.1. Existing Conditions

Analysis of the simulation results for the existing conditions in the watershed (Table 6.13) shows that contributions from livestock direct deposit dominate the in-stream concentrations of *E. coli*. Contributions from wildlife direct deposit and pervious land surfaces also contribute significant amounts to the average daily *E. coli* concentration. The results in this table were taken as the average daily contributions for the allocation simulation period, irrespective of the magnitude of the concentration or the flow rate (factors that were considered in the earlier section detailing the source breakdown used in the calibration). Table 6.13 gives an idea of what sources will be the dominant contributors to the instantaneous *E. coli* concentrations, and thus what sources will control the violations of the single sample standard.

The contribution of each of the sources listed in Table 6.13 to the calendar-month geometric mean *E. coli* concentration is shown in Figure 6.6. The ‘PLS’ category in Figure 6.6 includes both the ‘nonpoint source loadings from pervious land segments’ and the ‘interflow and groundwater contribution’ categories from Table 6.13. Because contributions from impervious surfaces only occur during rainfall events, there are many days with zero concentration from impervious areas; therefore, the calendar month geometric mean of impervious contributions is zero and does not appear in Figure 6.6.

Contributions from point sources hover around 1 cfu/100 mL and are not presented in the figure.

Table 6.13. Relative contributions of different *E. coli* sources to the overall *E. coli* concentration for existing conditions in the Upper Pigg River watershed.

Source	Mean Daily *E. coli* Concentration by Source, cfu/100 mL	Relative Contribution by Source
All Sources	250	
Nonpoint source loadings from pervious land segments	45	18%
Direct nonpoint source loadings to the stream from wildlife	45	18%
Direct nonpoint source loadings to the stream from livestock	140	56%
Interflow and groundwater contribution	5	2%
Straight-pipe discharges to stream	13	5%
Nonpoint source loadings from impervious land use	0.4	<1%
Point Sources	1	<1%

*Contributions from point sources assumed to be discharging at their permitted limits

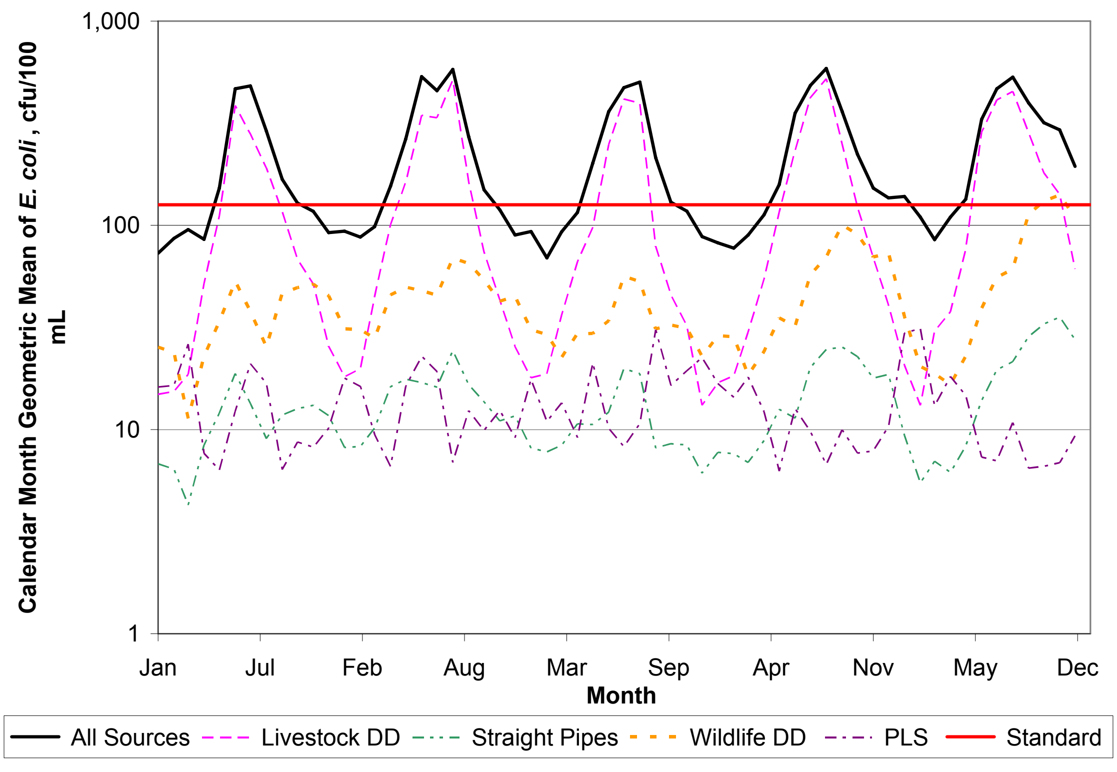

Figure 6.6. Contributions of different sources to the calendar-month geometric mean *E. coli* concentration in Upper Pigg River for existing conditions.

The contributions from livestock direct deposit also dominate the calendar-month geometric mean concentration. The cyclic nature of livestock direct deposit contributions is due to increased time spent in streams by livestock during summer months, combined with lower flow volumes; these two factors combine to increase bacteria concentrations during the summer months. Other sources also show a cyclic nature due to the change in flow volumes. Wildlife direct deposits are the next greatest contributor to the calendar-month geometric mean concentration. Straight pipes and PLS concentrations are similar in concentration contributions. From this graph, it is evident that violations of the calendar-month geometric mean standard will be most controlled by contributions from livestock direct deposit, and further that it will be impossible to meet the calendar-month geometric mean standard without reducing livestock direct deposit contributions. At several points in the last year of simulation, the dotted orange line representing wildlife direct deposits crosses the standard, showing that it will be impossible to meet the calendar-month geometric mean standard without reducing wildlife direct deposit contributions.

6.5.2. Allocation Scenarios

A variety of allocation scenarios were evaluated to meet the *E. coli* TMDL goal of a calendar-month geometric mean concentration less than 126 cfu/100 mL and a single-sample maximum concentration of less than 235 cfu/100 mL. The scenarios and results are summarized in Table 6.14; recall that these reductions are those used for modeling, and implementation of these reductions will require implementation of BMPs as discussed at the beginning of this chapter. Story Creek is a tributary to the Upper Pigg River watershed. With the exception of the baseline run, all scenarios presented in Table 6.14 include the successful allocation scenario 05 from Story Creek applied to the Story Creek portion of the watershed. Two successful scenarios were found to meet the standards for Upper Pigg River.

Table 6.14. Bacteria allocation scenarios for the Upper Pigg River watershed.

Scenario Number	Required Fecal Coliform Loading Reductions to Meet the *E. coli* Standards, %						% Violation of *E. coli* Standard	
	Live-stock DD	Loads from Cropland	Loads from Pasture	Wildlife DD	Straight Pipes	Loads from Residential	Geomean	Single Sample
Unsuccessful Scenarios								
Baseline Future Conditions	0	0	0	0	0	0	60	38
01*	100	100	100	0	100	100	2	0
02*	100	0	90	5	100	85	0	0.11
Successful Scenarios								
03*	100	100	100	5	100	100	0	0
04*	100	0	95	5	100	90	0	0

*Scenarios include successful scenario 05 from Table 6.8 applied to the Story Creek portion of the watershed.

Table 6.14 includes two categories of scenarios: those that were successful and those that were unsuccessful. Presentation of the unsuccessful scenarios illustrates the need for the reductions called for in the successful scenarios. Unsuccessful scenario 01 shows, as supported by Figure 6.6, that eliminating all anthropogenic sources of bacteria in the watershed will not bring Upper Pigg River into compliance with either *E. coli* standard. However, it does come close, and a 5% reduction in wildlife direct deposits will meet the standard, as shown in successful scenario 03. Successful scenario 03 shows the minimum wildlife direct deposit reductions needed to bring the watershed into compliance with the calendar-month geometric mean standard, with all anthropogenic sources eliminated.

As a general rule, direct deposit sources (wildlife, livestock, and straight pipes) control violations of the calendar-month geometric mean standard. These three sources control the constant inputs to the water body, and thus control the geometric mean of the daily average predictions over the entire month. Overland sources (runoff from pasture, cropland, forest, and residential areas) are generally more important to the violations of the single sample standard, as these sources control the large spikes in bacteria concentration predictions that occur after storm events. Given these general rules, and knowing that the calendar-month standard was the controlling factor dictating the reductions called for in Table 6.14, it was hypothesized that lower reductions could be called for from overland sources without requiring additional reductions from wildlife direct deposits. For scenarios 02 and 04, the wildlife direct deposit reductions were held constant at the minimum value to achieve standards compliance determined from scenarios 01 and 03. Reductions called for from overland sources were then altered. In this way, relatively minor contributors to the bacteria load (e.g., cropland, see later in this section) were not called to a 100% reduction. Unsuccessful scenario 02 demonstrates that cropland sources do not contribute a significant amount to the violations of either standard, and that high reductions are still needed from pasture and residential sources. Successful scenario 04 requires a larger reduction from the primary source of overland bacteria loading (pasture), and a significant reduction from the next major source of bacteria (residential). Because scenario 04 is a more equitable and achievable scenario, it has been chosen for summary in the rest of this section. Either scenario 03 or 04 could be chosen as the successful scenario by the stakeholder committee. Figure 6.7 displays the simulated daily average and calendar-month geometric mean concentrations in Upper Pigg River for scenario 04, along with the two *E. coli* standards.

Loadings for the existing conditions, baseline future conditions, and the successful TMDL allocation scenario (04) are presented for nonpoint sources by land use in Table 6.15 and for direct nonpoint sources in Table 6.16. These loads are only for the non-Story Creek portions of the Upper Pigg River watershed. The fecal coliform loads presented in these tables are the fecal coliform loads that result in in-stream *E. coli* concentrations that meet the applicable *E. coli* water quality standards after application of the VADEQ fecal coliform to *E. coli* translator to the HSPF-predicted mean daily fecal coliform concentrations.

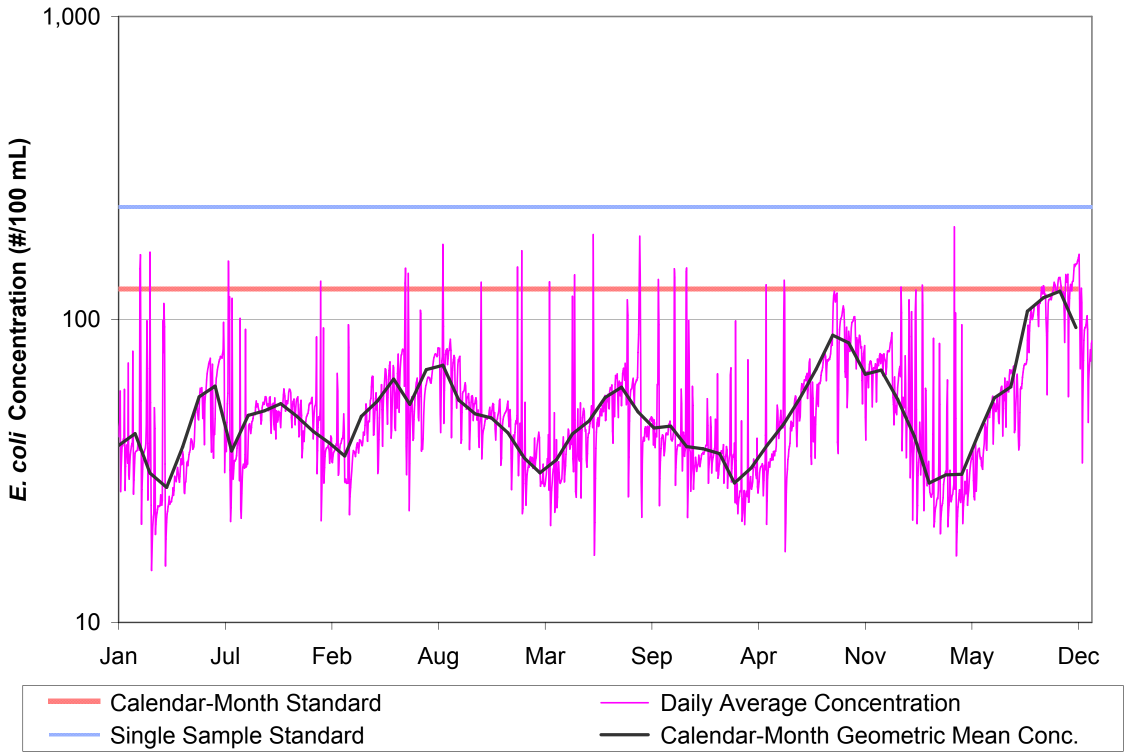

Figure 6.7. Simulated *E. coli* concentrations for the successful allocation scenario (04) for Upper Pigg River.

Table 6.15. Annual nonpoint source fecal coliform loads under existing and future conditions and corresponding reductions for allocation scenario 04 for Upper Pigg River.

Land use category	Existing Conditions*		Future Conditions*		Allocation Scenario*	
	Existing Conditions Load ($x10^{12}$ cfu/yr)	Percent of total land deposited load from nonpoint sources	Future Conditions Load ($x10^{12}$ cfu/yr)	Percent of total land deposited load from nonpoint sources	TMDL nonpoint source allocation load ($x10^{12}$ cfu/yr)	Percent Reduction from Future Load
Cropland	85	1%	63	1%	63	0%
Pasture	9,100	81%	9,119	81%	456	95%
Residential†	1,301	12%	1,350	12%	135	90%
Forest	703	6%	709	6%	709	0%
Total	11,189		11,241		1,363	88%

*Loads presented are for the non-Story Creek portion of the Upper Pigg River watershed
†Includes loads applied to pervious areas of both High and Low Density Residential

Table 6.16. Annual direct nonpoint source fecal coliform loads under existing and future conditions and corresponding reductions for TMDL allocation scenario 04 for Upper Pigg River.

Source	Existing Conditions*		Future Conditions*		Allocation Scenario*	
	Existing Conditions Load ($x10^{12}$ cfu/yr)	Percent of total direct deposited load from direct nonpoint source	Future Conditions Load ($x10^{12}$ cfu/yr)	Percent of total direct deposited load from direct nonpoint source	TMDL direct nonpoint source allocation load ($x10^{12}$ cfu/yr)	Percent Reduction from Future Load
Livestock in Streams	97	69%	97	69%	0	100%
Straight Pipes	9	6%	9	6%	0	100%
Wildlife in Streams	35	25%	35	25%	33	5%
Total	141		141		33	76%

*Loads presented are for the non-Story Creek portion of the Upper Pigg River watershed

6.5.3. Waste Load Allocation

Aside from the permitted facility in the Story Creek portion of the watershed, no permitted facilities currently exist in the Upper Pigg River watershed. However, to account for future growth in the area, a waste load allocation of <1% of the TMDL was modeled for Upper Pigg River.

6.5.4. Summary of Upper Pigg River's TMDL Allocation Scenario for Bacteria

A TMDL for *E. coli* has been developed for Upper Pigg River. The TMDL addresses the following issues:

1. The TMDL meets both the calendar-month geometric mean and single sample water quality standards.
2. Because *E. coli* loading data were not available to quantify nonpoint source bacterial loads, available fecal coliform loading data were used as input to HSPF. HSPF was then used to simulate in-stream fecal coliform concentrations. The VADEQ fecal coliform to *E. coli* concentration translator equation was then used to convert the simulated fecal coliform concentrations to *E. coli* concentrations.

3. The TMDL was developed taking into account all fecal bacteria sources (anthropogenic and natural) from both point and nonpoint sources.
4. An implicit margin of safety (MOS) was incorporated by utilizing professional judgment and conservative estimates of model parameters.
5. Both high- and low-flow stream conditions were considered while developing the TMDL. In the Upper Pigg River watershed, low stream flow was found to be the environmental condition most likely to cause a violation of the geometric mean criterion; high stream flow conditions after storm events were most likely to cause violations of the single sample criterion; because the TMDL was developed using a continuous simulation model, it applies to both high- and low-flow conditions.
6. Both the flow regime and bacteria loading to Upper Pigg River are seasonal. The TMDL accounts for these seasonal effects.

The selected *E. coli* TMDL allocation that meets both *E. coli* criteria requires a 100% reduction in cattle direct deposits to the stream; 100% reduction in straight pipe contributions; 5% reduction in wildlife direct deposits to the stream; 95% reduction from pasture areas; and 90% reduction from residential surfaces. Using equation 6.1, the summary of the bacteria TMDL for Upper Pigg River for the selected allocation scenario (04) is given in Table 6.17. The table reports both the TMDL for the entire watershed area (including Story Creek) and the area of the Upper Pigg River watershed excluding the Story Creek watershed.

Table 6.17. Annual *E. coli* loadings (cfu/yr) used for the Upper Pigg River bacteria TMDL.

Parameter	Area Covered	ΣWLA	ΣLA	MOS*	TMDL
E. coli	Upper Pigg River	1.18×10^{12} *(VA0029254 = 6.99×10^{11} <1% of TMDL = 4.83×10^{11})*	6.72×10^{13}	--	6.84×10^{13}
	Upper Pigg R. Excluding Story Creek	<1%	4.86×10^{13}	--	4.91×10^{13}

*Implicit MOS

6.6. 'Leesville Lake' – Pigg River Bacteria TMDL

Throughout this section, the Leesville Lake – Pigg River impairment will be referred to as the 'LL-Pigg River' impairment.

6.6.1. Existing Conditions

Analysis of the simulation results for the existing conditions in the watershed (Table 6.18) shows that three major source categories contribute about equally to the in-stream concentrations of *E. coli*: nonpoint source loadings from pervious land segments, direct nonpoint source loadings from wildlife, and direct nonpoint source loadings from livestock. Other sources only contribute a minor amount to the average daily bacteria concentration. The results in this table were taken as the average daily contributions for the allocation simulation period, irrespective of the magnitude of the concentration or the flow rate (factors that were considered in the earlier section detailing the source breakdown used in the calibration). Table 6.18 gives an idea of what sources will be the dominant contributors to the instantaneous *E. coli* concentrations, and thus what sources will control the violations of the single sample standard.

Table 6.18. Relative contributions of different *E. coli* sources to the overall *E. coli* concentration for existing conditions in the LL-Pigg River watershed.

Source	Mean Daily *E. coli* concentration by Source, cfu/100 mL	Relative Contribution by Source
All Sources	159	
Nonpoint source loadings from pervious land segments	49	31%
Direct nonpoint source loadings to the stream from wildlife	51	32%
Direct nonpoint source loadings to the stream from livestock	52	33%
Interflow and groundwater contribution	3	2%
Straight-pipe discharges to stream	2	1%
Nonpoint source loadings from impervious land use	0.2	<1%
Point Sources*	0.6	<1%

*Contributions from point sources assumed to be discharging at their permitted limits

The contributions from each of the sources listed in Table 6.18 to the calendar-month geometric mean *E. coli* concentration are shown in Figure 6.8. The ‘PLS’ category in Figure 6.8 includes both the ‘nonpoint source loadings from pervious land segments’ and the ‘interflow and groundwater contribution’ categories from Table 6.18. Because contributions from impervious surfaces only occur during rainfall events, there are many days with zero concentration from impervious areas; therefore, the calendar month geometric mean of impervious contributions is zero and does not appear in Figure 6.8. Contributions from point sources hover around 0.6 cfu/100 mL and are not presented in the figure.

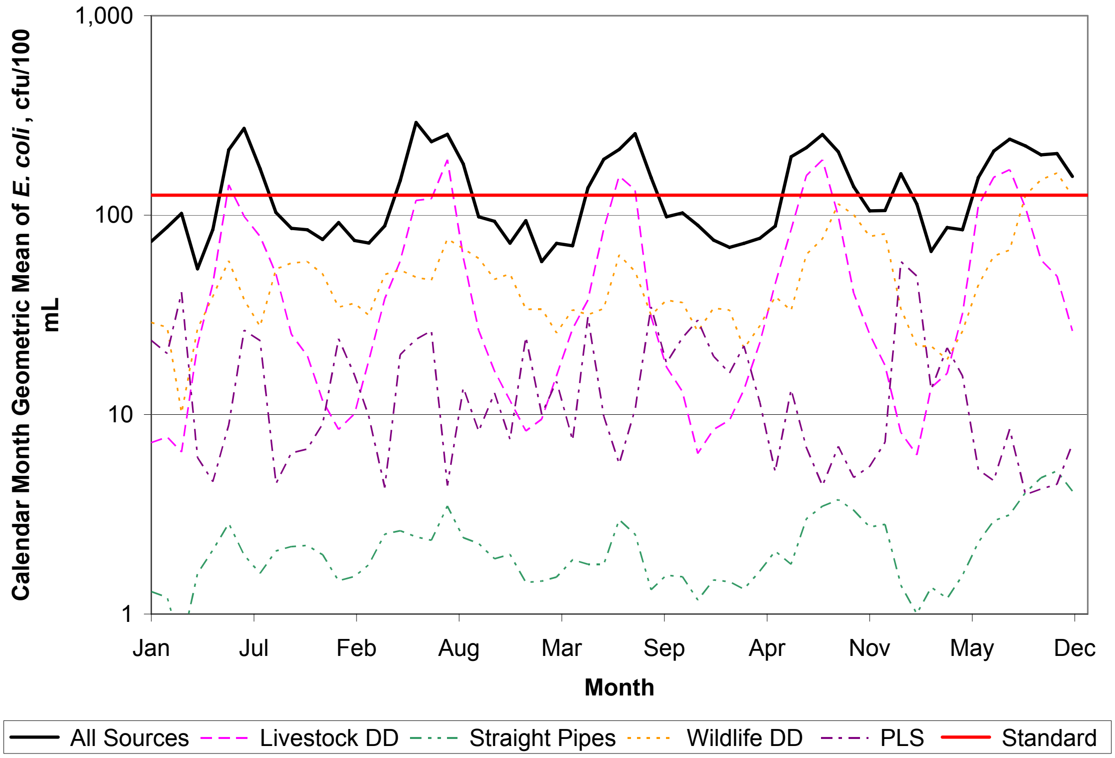

Figure 6.8. Contributions of different sources to the calendar-month geometric mean *E. coli* concentration in LL-Pigg River for existing conditions.

The contributions from livestock direct deposit and wildlife direct deposit dominate the calendar-month geometric mean concentration. The cyclic nature of livestock direct deposit contributions is due to increased time spent in streams by livestock during summer months, combined with lower flow volumes; these two factors combine to increase bacteria concentrations during the summer months. Other sources also show a cyclic nature due to the change in flow volumes. PLS sources are also significant contributors to the calendar month geometric mean concentrations. Straight pipes do contribute, but at a much lower concentration than the other sources in the graph. From this graph, it is evident that violations of the calendar-month geometric mean standard will be most controlled by contributions from livestock direct deposit, and further that it will be impossible to meet the calendar-month geometric mean standard without reducing livestock direct deposit contributions. In the last months of simulation of simulation the dotted orange line representing wildlife direct deposits crosses the standard, showing that it will be impossible to meet the calendar-month geometric mean standard without reducing wildlife direct deposit contributions.

6.6.2. Allocation Scenarios

A variety of allocation scenarios were evaluated to meet the *E. coli* TMDL goal of a calendar-month geometric mean concentration less than 126 cfu/100 mL and a single-sample maximum concentration of less than 235 cfu/100 mL. The scenarios and results are summarized in Table 6.19; recall that these reductions are those used for modeling, and implementation of these reductions will require implementation of BMPs as discussed at the beginning of this chapter. The LL-Pigg River watershed includes Story Creek, Snow Creek, and Upper Pigg River. With the exception of the baseline run, all scenarios presented in Table 6.19 include the successful allocation scenarios 04 from Snow Creek, 05 from Story Creek, and 04 from Upper Pigg River applied to the appropriate portions of the watershed. Two successful scenarios were found to meet the standards for LL-Pigg River.

Table 6.19. Bacteria allocation scenarios for the LL-Pigg River watershed.

Scenario Number	Required Fecal Coliform Loading Reductions to Meet the *E. coli* Standards, %						% Violation of *E. coli* Standard	
	Live-stock DD	Loads from Cropland	Loads from Pasture	Wildlife DD	Straight Pipes	Loads from Residential	Geomean	Single Sample
Unsuccessful Scenarios								
Baseline Future Conditions	0	0	0	0	0	0	43	15
1*	100	100	100	0	100	100	5	0
2*	100	100	100	25	100	100	2	0
3*	100	0	90	25	100	90	0	0.16
Successful Scenarios								
4*	100	100	100	30	100	100	0	0
5*	100	0	95	30	100	90	0	0

*Scenarios 1-5 include reductions called for in scenario 04 for Snow Creek (Table 6.3), 05 for Story Creek (Table 6.8), and 04 for Upper Pigg River (Table 6.14) applied to the appropriate areas of the watershed.

Table 6.19 includes two categories of scenarios: those that were successful and those that were unsuccessful. Presentation of the unsuccessful scenarios illustrates the need for the reductions called for in the successful scenarios. Unsuccessful scenario 01 shows, as supported by Figure 6.8, that eliminating all anthropogenic sources of bacteria in the watershed will not bring LL-Pigg River into compliance with the calendar-month geometric mean *E. coli* standard. Scenario 02 demonstrates that even a 25% reduction in wildlife direct deposits is not sufficient to meet the calendar-month geometric mean standard. Successful scenario 04 shows the minimum wildlife direct deposit reductions needed to bring the watershed into compliance with the calendar-month geometric mean standard, with all anthropogenic sources eliminated.

As a general rule, direct deposit sources (wildlife, livestock, and straight pipes) control violations of the calendar-month geometric mean standard. These three sources control the constant inputs to the water body, and thus control the geometric mean of the daily average predictions over the entire month. Overland sources (runoff from pasture, cropland, forest, and residential areas) are generally more important to the violations of the single sample standard, as these sources control the large spikes in bacteria concentration predictions that occur after storm events. Given these general rules, and knowing that the calendar-month standard was the controlling factor dictating the reductions called for in Table 6.19, it was hypothesized that lower reductions could be called for from overland sources without requiring additional reductions from wildlife direct deposits. For scenarios 03 and 05, the wildlife direct deposit reductions were held constant at the minimum value to achieve standards compliance determined from scenarios 02 and 04. Reductions called for from overland sources were then altered. In this way, relatively minor contributors to the bacteria load (e.g., cropland, see later in this section) were not called to a 100% reduction. Unsuccessful scenario 03 demonstrates that cropland sources do not contribute a significant amount to the violations of either standard, and that high reductions are still needed from pasture and residential sources. Successful scenario 05 requires a larger reduction from the primary source of overland bacteria loading (pasture), and a significant reduction from the next major source of bacteria (residential). Although not explicitly modeled in this study, concerns have been raised regarding the potential for leaking sewer lines in the watershed; these should be addressed while addressing residential sources during implementation. Because scenario 05 is a more equitable and achievable scenario, it has been chosen for summary in the rest of this section. Either scenario 04 or 05 could be chosen as the successful scenario by the stakeholder committee. Figure 6.9 displays the simulated daily average and calendar-month geometric mean concentrations at the LL-Pigg River outlet for scenario 05, along with the two *E. coli* standards.

Loadings for the existing conditions, baseline future conditions, and the successful TMDL allocation scenario (05) are presented for nonpoint sources by land use in Table 6.20 and for direct nonpoint sources in Table 6.21. These loads are only for the portions of the LL-Pigg River watershed not in Snow Creek, Story Creek, or Upper Pigg River. The fecal coliform loads presented in these tables are the fecal coliform loads that result in in-stream *E. coli* concentrations that meet the applicable *E. coli* water quality standards after application of the VADEQ fecal coliform to *E. coli* translator to the HSPF-predicted mean daily fecal coliform concentrations.

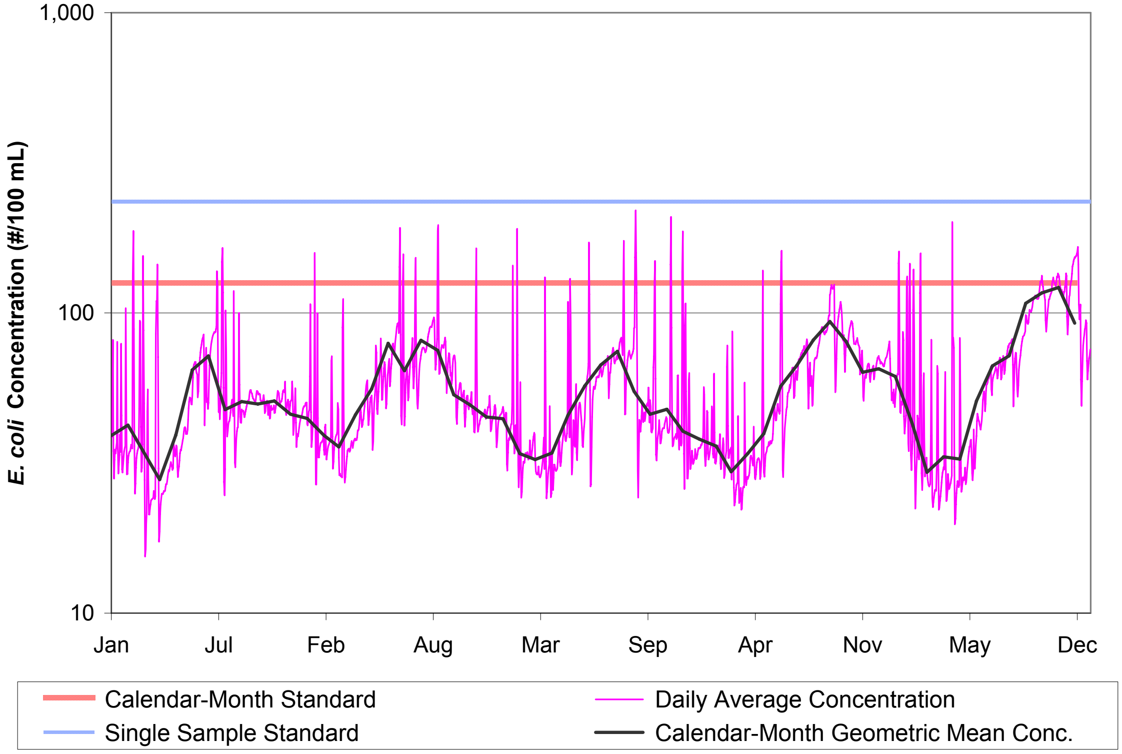

Figure 6.9. Simulated *E. coli* concentrations for the successful allocation scenario (05) for LL-Pigg River.

Table 6.20. Annual nonpoint source fecal coliform loads under existing and future conditions and corresponding reductions for allocation scenario 05 for LL-Pigg River.

Land use category	Existing Conditions*		Future Conditions*		Allocation Scenario*	
	Existing Conditions Load ($x10^{12}$ cfu/yr)	Percent of total land deposited load from nonpoint sources	Future Conditions Load ($x10^{12}$ cfu/yr)	Percent of total land deposited load from nonpoint sources	TMDL nonpoint source allocation load ($x10^{12}$ cfu/yr)	Percent Reduction from Future Load
Cropland	201	1%	201	1%	201	0%
Pasture	29,583	84%	29,585	83%	1,479	95%
Residential†	2,506	7%	2,686	8%	269	90%
Forest	3,077	9%	3,077	9%	3,077	0%
Total	35,367		35,549		5,026	86%

*Loads presented are for the portion of the LL-Pigg River watershed not in Snow Creek, Story Creek, or Upper Pigg River

†Includes loads applied to pervious areas of both High and Low Density Residential

Table 6.21. Annual direct nonpoint source fecal coliform loads under existing and future conditions and corresponding reductions for TMDL allocation scenario 05 for LL-Pigg River.

Source	Existing Conditions*		Future Conditions*		Allocation Scenario*	
	Existing Conditions Load ($x10^{12}$ cfu/yr)	**Percent of total direct deposited load from direct nonpoint source**	**Future Conditions Load ($x10^{12}$ cfu/yr)**	**Percent of total direct deposited load from direct nonpoint source**	**TMDL direct nonpoint source allocation load ($x10^{12}$ cfu/yr)**	**Percent Reduction from Future Load**
Livestock in Streams	204	44%	204	44%	0	100%
Straight Pipes	7	2%	7	2%	0	100%
Wildlife in Streams	255	55%	255	55%	179	30%
Total	466		466		179	62%

*Loads presented are for the portion of the LL-Pigg River watershed not in Snow Creek, Story Creek, or Upper Pigg River

6.6.3. Waste Load Allocation

In addition to the permitted facility in the Story Creek portion of the watershed, one permitted facility currently exists in the watershed and one other is scheduled to go online in the future (Table 6.22). The permitted sources in Table 6.22 were represented in the allocation scenario by their current permit conditions; no reductions were required from the point sources in the TMDL. Current permit requirements are expected to result in attainment of the *E. coli* WLA as required by the TMDL. Point source contributions to bacteria concentrations, even in terms of maximum flow, are minimal. In addition, the point source facilities are required to discharge at or below the bacteria water quality criteria and therefore cannot cause a violation of those criteria without also violating their discharge permits. Because the permits for these facilities already protect against violating the bacteria water quality standard, there is no need to modify the existing permit.

Table 6.22. Point sources discharging into the LL-Pigg River watershed.

Permit Number	Facility Name	Flow (gpd)	Permitted *E. coli* Conc. (cfu/100 mL)	Permitted *E. coli* Load (cfu/yr)	Allocated *E. coli* Load (cfu/yr)
VA0091103†	Franklin County Commer Center WWTP	2×10^4	126	3.48×10^{10}	3.48×10^{10}
VA0085952	Rocky Mount Town STP	2×10^6	126	3.48×10^{12}	3.48×10^{12}

†Not currently online

6.6.4. Summary of LL-Pigg River's TMDL Allocation Scenario for Bacteria

A TMDL for *E. coli* has been developed for Leesville Lake-Pigg River. The TMDL addresses the following issues:

1. The TMDL meets both the calendar-month geometric mean and single sample water quality standards.
2. Because *E. coli* loading data were not available to quantify nonpoint source bacterial loads, available fecal coliform loading data were used as input to HSPF. HSPF was then used to simulate in-stream fecal coliform concentrations. The VADEQ fecal coliform to *E. coli* concentration translator equation was then used to convert the simulated fecal coliform concentrations to *E. coli* concentrations.
3. The TMDL was developed taking into account all fecal bacteria sources (anthropogenic and natural) from both point and nonpoint sources.
4. An implicit margin of safety (MOS) was incorporated by utilizing professional judgment and conservative estimates of model parameters.
5. Both high- and low-flow stream conditions were considered while developing the TMDL. In the LL-Pigg River watershed, low stream flow was found to be the environmental condition most likely to cause a violation of the geometric mean criterion; high stream flow conditions after storm events were most likely to cause violations of the single sample criterion; because the TMDL was developed using a

continuous simulation model, it applies to both high- and low-flow conditions.

6. Both the flow regime and bacteria loading to LL-Pigg River are seasonal. The TMDL accounts for these seasonal effects.

The selected *E. coli* TMDL allocation that meets both *E. coli* criteria requires a 100% reduction in cattle direct deposits to the stream; 100% reduction in straight pipe contributions; 30% reduction in wildlife direct deposits to the stream; 95% reduction from pasture areas; and 90% reduction from residential surfaces. Using equation 6.1, the summary of the bacteria TMDL for LL-Pigg River for the selected allocation scenario (05) is given in Table 6.12. The table reports both the TMDL for the entire watershed area and for the area excluding Snow Creek, Story Creek, and Upper Pigg River.

Table 6.23. Annual *E. coli* loadings (cfu/yr) at the watershed outlet used for the LL-Pigg River bacteria TMDL.

Parameter	Area Covered	ΣWLA	ΣLA	MOS*	TMDL
E. coli	LL-Pigg River	5.54×10^{12} *(VA0029254 = 6.99×10^{11} VA0091103 = 3.48×10^{10} VA0085952 = 3.48×10^{12} <1% of TMDL for Snow and U. Pigg =1.33×10^{12})*	3.43×10^{14}	--	3.48×10^{14}
	LL-Pigg R. Excluding Snow Cr, Story Cr, and Upper Pigg R.	3.51×10^{12} *(VA0091103 = 3.48×10^{10} VA0085952 = 3.48×10^{12})*	1.91×10^{14}	--	1.94×10^{14}

*Implicit MOS

6.7. Old Womans Creek Bacteria TMDL

6.7.1. Existing Conditions

Analysis of the simulation results for the existing conditions in the watershed (Table 6.24) shows that wildlife direct deposit contributions dominate the average daily in-stream bacteria concentration. Livestock direct deposit sources, though not contributing quite as much to the mean daily concentration, are still a significant contributor. The results in this table were taken as the average daily contributions for the allocation simulation period, irrespective of the magnitude of the concentration or the flow rate (factors that were considered in the earlier section detailing the source breakdown used in the calibration). Table 6.24 gives an idea of what sources will be the dominant contributors to the instantaneous *E. coli* concentrations, and thus what sources will control the violations of the single sample standard.

Table 6.24. Relative contributions of different *E. coli* sources to the overall *E. coli* concentration for existing conditions in the Old Womans Creek watershed.

Source	Mean Daily *E. coli* concentration by Source, cfu/100 mL	Relative Contribution by Source
All Sources	185	
Nonpoint source loadings from pervious land segments	15	8%
Direct nonpoint source loadings to the stream from wildlife	102	55%
Direct nonpoint source loadings to the stream from livestock	61	33%
Interflow and groundwater contribution	7	4%
Nonpoint source loadings from impervious land use	0.1	<1%

The contributions from each of the sources listed in Table 6.24 to the calendar-month geometric mean *E. coli* concentration are shown in Figure 6.10. The 'PLS' category in Figure 6.10 includes both the 'nonpoint source loadings from pervious land segments' and the 'interflow and groundwater contribution' categories from Table 6.24. Because contributions from impervious surfaces only occur during rainfall events, there are many days with zero concentration from impervious areas; therefore, the calendar month geometric mean of impervious contributions is zero and does not appear in Figure 6.10.

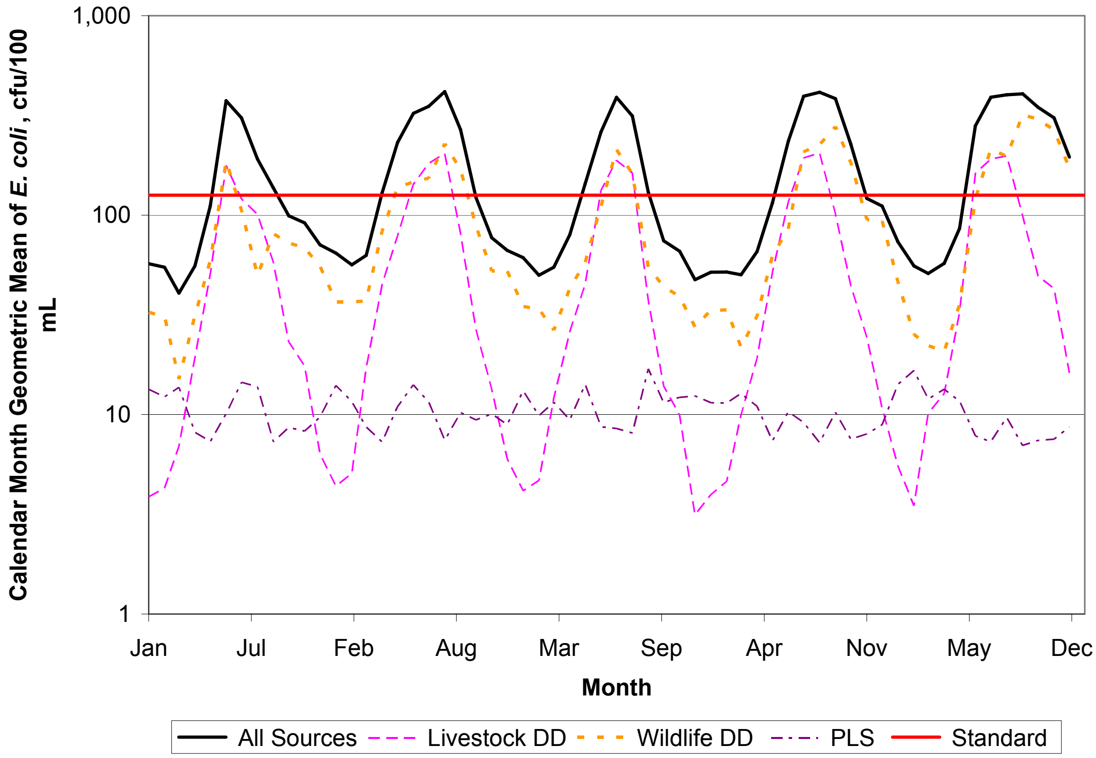

Figure 6.10. Contributions of different sources to the calendar-month geometric mean *E. coli* concentration in Old Womans Creek for existing conditions.

The contributions from livestock direct deposit and wildlife direct deposit dominate the calendar-month geometric mean concentration. The cyclic nature of livestock direct deposit contributions is due to increased time spent in streams by livestock during summer months, combined with lower flow volumes; these two factors combine to increase bacteria concentrations during the summer months. Other sources also show a cyclic nature due to the change in flow volumes. PLS sources are not significant contributors to the calendar month geometric mean concentrations. From this graph, it is evident that violations of the calendar-month geometric mean standard will be most controlled by contributions from both livestock and wildlife direct deposit, and further that it will be impossible to meet the calendar-month geometric mean standard without reducing contributions from both of these sources.

6.7.2. Allocation Scenarios

A variety of allocation scenarios were evaluated to meet the *E. coli* TMDL goal of a calendar-month geometric mean concentration less than 126 cfu/100 mL and a single-sample maximum concentration of less than 235 cfu/100 mL. The scenarios and results are summarized in Table 6.25; recall that these reductions are those used for modeling, and implementation of these reductions will require implementation of BMPs as discussed at the beginning of this chapter. Two successful scenarios were found to meet the standards for Old Womans Creek.

Table 6.25. Bacteria allocation scenarios for the Old Womans Creek watershed.

Scenario Number	Required Fecal Coliform Loading Reductions to Meet the *E. coli* Standards, %					% Violation of *E. coli* Standard	
	Livestock DD	Loads from Cropland	Loads from Pasture	Wildlife DD	Loads from Residential	Geomean	Single Sample
Unsuccessful Scenarios							
Existing Conditions	0	0	0	0	0	63	47
1	100	100	100	0	100	33	14
2	100	100	100	65	100	2	0
3	100	0	90	67	80	0	0.05
Successful Scenarios							
4	100	100	100	67	100	0	0
5	100	0	90	67	85	0	0

Table 6.25 includes two categories of scenarios: those that were successful and those that were unsuccessful. Presentation of the unsuccessful scenarios illustrates the need for the reductions called for in the successful scenarios. Unsuccessful scenario 01 shows, as supported by Figure 6.10, that eliminating all anthropogenic sources of bacteria in the watershed will not bring Old Womans Creek into compliance with the calendar-month geometric mean *E. coli* standard. Scenario 02 demonstrates that even a 65% reduction in wildlife direct deposits is not sufficient to meet the calendar-month geometric mean standard. Successful scenario 04 shows the minimum wildlife direct deposit

reductions needed to bring the watershed into compliance with the calendar-month geometric mean standard, with all anthropogenic sources eliminated.

As a general rule, direct deposit sources (wildlife and livestock) control violations of the calendar-month geometric mean standard. These three sources control the constant inputs to the water body, and thus control the geometric mean of the daily average predictions over the entire month. Overland sources (runoff from pasture, cropland, forest, and residential areas) are generally more important to the violations of the single sample standard, as these sources control the large spikes in bacteria concentration predictions that occur after storm events. Given these general rules, and knowing that the calendar-month standard was the controlling factor dictating the reductions called for in Table 6.25, it was hypothesized that lower reductions could be called for from overland sources without requiring additional reductions from wildlife direct deposits. For scenarios 03 and 05, the wildlife direct deposit reductions were held constant at the minimum value to achieve standards compliance determined from scenarios 02 and 04. Reductions called for from overland sources were then altered. In this way, relatively minor contributors to the bacteria load (e.g., cropland, see later in this section) were not called to a 100% reduction. Unsuccessful scenario 03 demonstrates that cropland sources do not contribute a significant amount to the violations of either standard, and that high reductions are still needed from pasture and residential sources. Successful scenario 05 requires a larger reduction from the primary source of overland bacteria loading (pasture), and a significant reduction from the next major anthropogenic source of bacteria (residential). Because scenario 05 is a more equitable and achievable scenario, it has been chosen for summary in the rest of this section. Either scenario 04 or 05 could be chosen as the successful scenario by the stakeholder committee. Figure 6.11 displays the simulated daily average and calendar-month geometric mean concentrations at the Old Womans Creek outlet for scenario 05, along with the two *E. coli* standards.

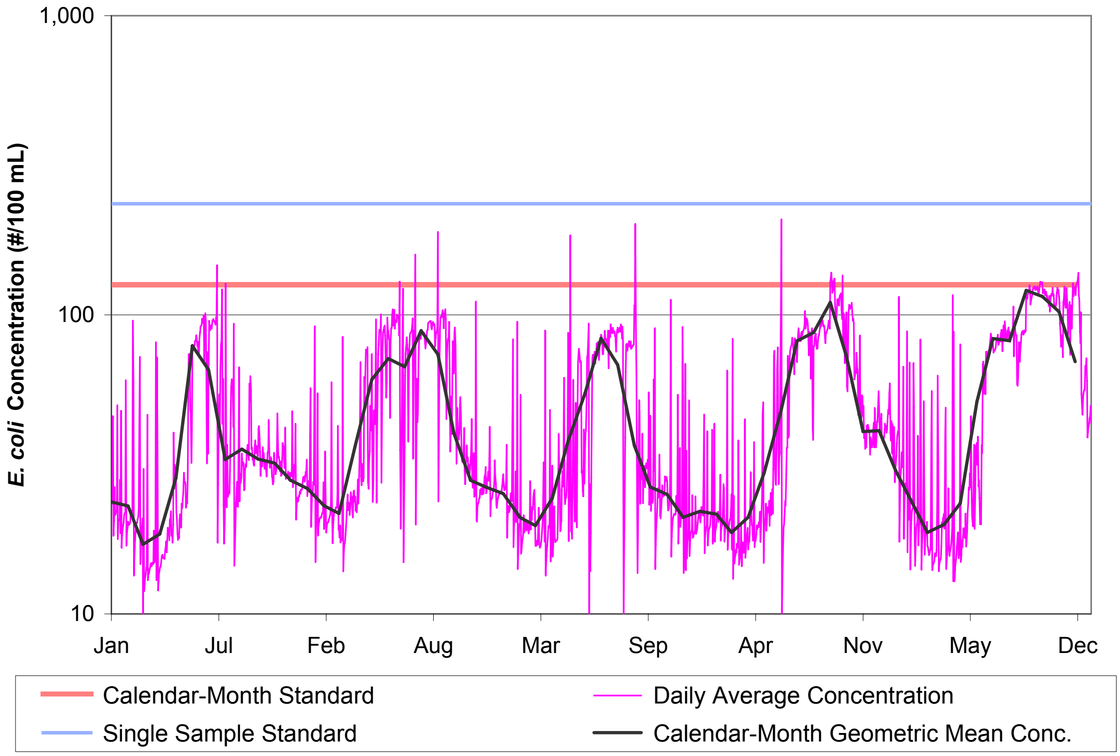

Figure 6.11. Simulated *E. coli* concentrations for the successful allocation scenario (05) for Old Womans Creek.

Loadings for the existing conditions and the successful TMDL allocation scenario (05) are presented for nonpoint sources by land use in Table 6.26 and for direct nonpoint sources in Table 6.27. The fecal coliform loads presented in these tables are the fecal coliform loads that result in in-stream *E. coli* concentrations that meet the applicable *E. coli* water quality standards after application of the VADEQ fecal coliform to *E. coli* translator to the HSPF-predicted mean daily fecal coliform concentrations.

Table 6.26. Annual nonpoint source fecal coliform loads under existing conditions and corresponding reductions for allocation scenario 05 for Old Womans Creek.

Land use category	Existing Conditions: Existing Conditions Load ($x10^{12}$ cfu/yr)	Existing Conditions: Percent of total land deposited load from nonpoint sources	Allocation Scenario: TMDL nonpoint source allocation load ($x10^{12}$ cfu/yr)	Allocation Scenario: Percent Reduction from Future Load
Cropland	7	<1%	7	0%
Pasture	1,081	81%	108	90%
Residential*	92	7%	14	85%
Forest	156	12%	156	0%
Total	1,336		285	79%

*Includes loads applied to pervious areas of Low Density Residential

Table 6.27. Annual direct nonpoint source fecal coliform loads under existing conditions and corresponding reductions for TMDL allocation scenario 05 for Old Womans Creek.

Source	Existing Conditions: Existing Conditions Load ($x10^{12}$ cfu/yr)	Existing Conditions: Percent of total direct deposited load from direct nonpoint source	Allocation Scenario: TMDL direct nonpoint source allocation load ($x10^{12}$ cfu/yr)	Allocation Scenario: Percent Reduction from Future Load
Livestock in Streams	5.7	43%	0	100%
Wildlife in Streams	7.7	57%	2.5	67%
Total	13.4		2.5	81%

6.7.3. Waste Load Allocation

No permitted facilities currently exist in the Old Womans Creek watershed. However, to account for future growth in the area, a waste load allocation of <1% of the TMDL was modeled for Old Womans Creek.

6.7.4. Summary of Old Womans Creek's TMDL Allocation Scenario for Bacteria

A TMDL for *E. coli* has been developed for Old Womans Creek. The TMDL addresses the following issues:

1. The TMDL meets both the calendar-month geometric mean and single sample water quality standards.

2. Because *E. coli* loading data were not available to quantify nonpoint source bacterial loads, available fecal coliform loading data were used as input to HSPF. HSPF was then used to simulate in-stream fecal coliform concentrations. The VADEQ fecal coliform to *E. coli* concentration translator equation was then used to convert the simulated fecal coliform concentrations to *E. coli* concentrations.
3. The TMDL was developed taking into account all fecal bacteria sources (anthropogenic and natural) from both point and nonpoint sources.
4. An implicit margin of safety (MOS) was incorporated by utilizing professional judgment and conservative estimates of model parameters.
5. Both high- and low-flow stream conditions were considered while developing the TMDL. In the Old Womans Creek watershed, low stream flow was found to be the environmental condition most likely to cause a violation of the geometric mean criterion; high stream flow conditions after storm events were most likely to cause violations of the single sample criterion; because the TMDL was developed using a continuous simulation model, it applies to both high- and low-flow conditions.
6. Both the flow regime and bacteria loading to Old Womans Creek are seasonal. The TMDL accounts for these seasonal effects.

The selected *E. coli* TMDL allocation that meets both *E. coli* criteria requires a 100% reduction in cattle direct deposits to the stream; 67% reduction in wildlife direct deposits to the stream; 90% reduction from pasture areas; and 85% reduction from residential surfaces. Using equation 6.1, the summary of the bacteria TMDL for Old Womans Creek for the selected allocation scenario (05) is given in Table 6.28.

Table 6.28. Annual *E. coli* loadings (cfu/yr) at the watershed outlet used for the Old Womans Creek bacteria TMDL.

Parameter	**ΣWLA**	**ΣLA**	**MOS***	**TMDL**
E. coli	<1%	7.17×10^{12}	--	7.24×10^{12}

*Implicit MOS

Chapter 7: TMDL Implementation and Reasonable Assurance

Once a TMDL has been approved by EPA, measures must be taken to reduce pollution levels from both point and non point sources in the stream (see section 7.4.2). For point sources, all new or revised VPDES/NPDES permits must be consistent with the TMDL WLA pursuant to 40 CFR §122.44 (d)(1)(vii)(B) and must be submitted to EPA for approval. The measures for non point source reductions, which can include the use of better treatment technology and the installation of best management practices (BMPs), are implemented in an iterative process that is described along with specific BMPs in the implementation plan. The process for developing an implementation plan has been described in the "TMDL Implementation Plan Guidance Manual", published in July 2003 and available upon request from the DEQ and DCR TMDL project staff or at http://www.deq.virginia.gov/tmdl/implans/ipguide.pdf. With successful completion of implementation plans, local stakeholders will have a blueprint to restore impaired waters and enhance the value of their land and water resources. Additionally, development of an approved implementation plan may enhance opportunities for obtaining financial and technical assistance during implementation.

7.1. Staged Implementation

In general, Virginia intends for the required bacteria reductions to be implemented in an iterative process that first addresses those sources with the largest impact on water quality. For example, in agricultural areas of the watershed, the most promising best management practice is livestock exclusion from streams. This has been shown to be very effective in lowering bacteria concentrations in streams, both by reducing the cattle deposits themselves and by providing additional riparian buffers.

Additionally, in both urban and rural areas, reducing the human bacteria loading from failing septic systems should be a primary implementation focus because of its health implications. This component could be implemented through education on septic tank pump-outs as well as a septic system repair/replacement program and the use of alternative waste treatment systems.

In urban areas, reducing the human bacteria loading from leaking sewer lines could be accomplished through a sanitary sewer inspection and management program. Other BMPs that might be appropriate for controlling urban wash-off from parking lots and roads and that could be readily implemented may include more restrictive ordinances to reduce fecal loads from pets, improved garbage collection and control, and improved street cleaning.

The iterative implementation of BMPs in the watershed has several benefits:

1. It enables tracking of water quality improvements following BMP implementation through follow-up stream monitoring;
2. It provides a measure of quality control, given the uncertainties inherent in computer simulation modeling;
3. It provides a mechanism for developing public support through periodic updates on BMP implementation and water quality improvements;
4. It helps ensure that the most cost effective practices are implemented first; and
5. It allows for the evaluation of the adequacy of the TMDL in achieving water quality standards.

Watershed stakeholders will have opportunity to participate in the development of the TMDL implementation plan. While specific goals for BMP implementation will be established as part of the implementation plan development, the following Stage 1 scenarios are targeted at controllable, anthropogenic bacteria sources and can serve as starting points for targeting BMP implementation activities.

7.2. Stage 1 Scenarios

The goal of the Stage 1 scenarios is to reduce the bacteria loadings from controllable sources (excluding wildlife) such that violations of the instantaneous criterion (235 cfu/100mL) are less than 10 percent. The Stage 1 scenarios were generated with the same model setup as was used for the TMDL allocation scenarios. It was estimated for modeling purposes that there are no straight pipes in the Old Womans Creek watershed. Should any be found during the implementation process, they should be eliminated as soon as possible since they would be illegally discharging fecal bacteria into Old Womans Creek and its tributaries.

7.2.1. Stage 1 Scenario for Snow Creek

There was one successful scenario for the Snow Creek watershed (Table 7.1). In part due to the livestock fencing already accomplished in this watershed, the Stage 1 implementation goal can be reached with just an additional 5% reduction in contributions from livestock direct deposits and elimination of straight pipe dischargers. *E. coli* concentrations resulting from application of the fecal coliform to *E. coli* translator equation to the Stage 1 fecal coliform concentrations are presented graphically in Figure 7.1.

Table 7.1. Allocation scenario for Stage 1 TMDL implementation for Snow Creek.

Single Sample Standard Percent Violation	Required Fecal Coliform Loading Reductions to Meet the Stage 1 Goal, %					
	Livestock DD	Loads from Cropland	Loads from Pasture	Wildlife DD	Straight Pipes	Loads from Residential
9	5	0	0	0	100	0

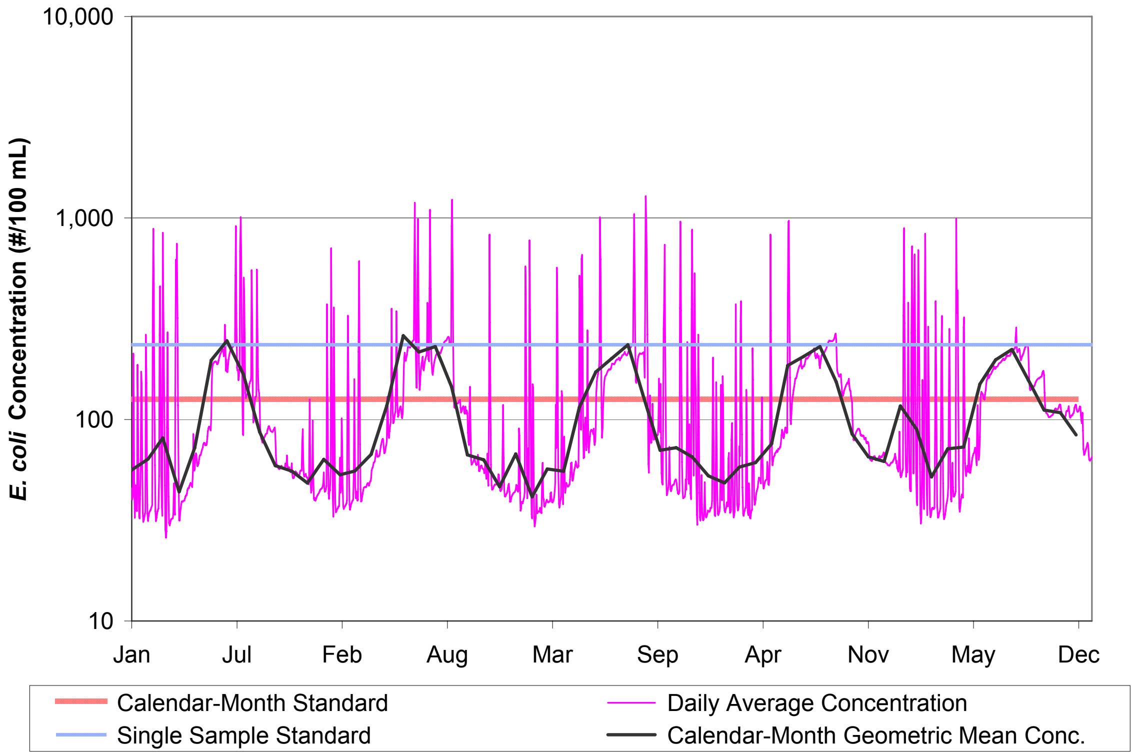

Figure 7.1. Simulated *E. coli* concentrations with the two bacteria standards for the Stage 1 implementation scenario for Snow Creek.

7.2.2. Stage 1 Scenario for Story Creek

There was one successful scenario for the Story Creek watershed (Table 7.2). The Stage 1 implementation goal for Story Creek can be reached with a 90% reduction in livestock direct deposits and a 100% reduction in contributions from straight pipes. Experimentation with the model showed the livestock direct deposit contributions to be so high that even extreme reductions in overland sources could not bring the violation rate below 10% without an accompanying extreme reduction in livestock direct deposits; this is supported by the breakdown of sources in the daily average *E. coli* concentration in Table 6.10. *E. coli* concentrations resulting from application of the fecal coliform to *E. coli* translator equation to the Stage 1 fecal coliform concentrations are presented graphically in Figure 7.2.

Table 7.2. Allocation scenario for Stage 1 TMDL implementation for Story Creek.

Single Sample Standard Percent Violation	Required Fecal Coliform Loading Reductions to Meet the Stage 1 Goal, %					
	Livestock DD	Loads from Cropland	Loads from Pasture	Wildlife DD	Straight Pipes	Loads from Residential
8	90	0	0	0	100	0

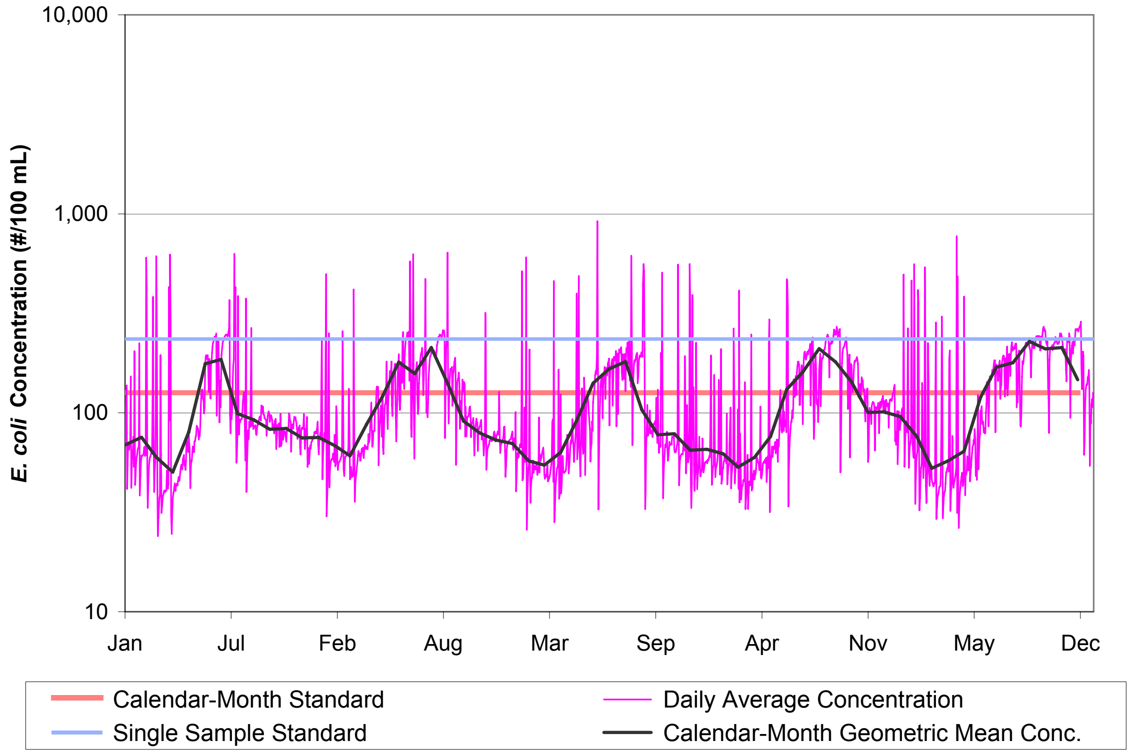

Figure 7.2. Simulated *E. coli* concentrations with the two bacteria standards for the Stage 1 implementation scenario for Story Creek.

7.2.3. Stage 1 Scenario for Upper Pigg River

There was one successful scenario for the Upper Pigg River watershed (Table 7.3). This scenario incorporates the reductions described in Section 7.2.2 for the Story Creek portion of the watershed. The reductions presented in Table 7.3 are for the non-Story Creek portion of the watershed. The Stage 1 implementation goal for Upper Pigg River can be accomplished with a 65% reduction in livestock direct deposits and 100% reduction in contributions from straight pipes. *E. coli* concentrations resulting from application of the fecal coliform to *E. coli* translator equation to the Stage 1 fecal coliform concentrations are presented graphically in Figure 7.3.

Table 7.3. Allocation scenario for Stage 1 TMDL implementation for Upper Pigg River.

Single Sample Standard Percent Violation	Required Fecal Coliform Loading Reductions to Meet the Stage 1 Goal, %*					
	Livestock DD	Loads from Cropland	Loads from Pasture	Wildlife DD	Straight Pipes	Loads from Residential
9	65	0	0	0	100	0

*Reductions apply to the non-Story Creek portion of the watershed; the Story Creek area is assumed to meet the reductions presented in Table 7.2

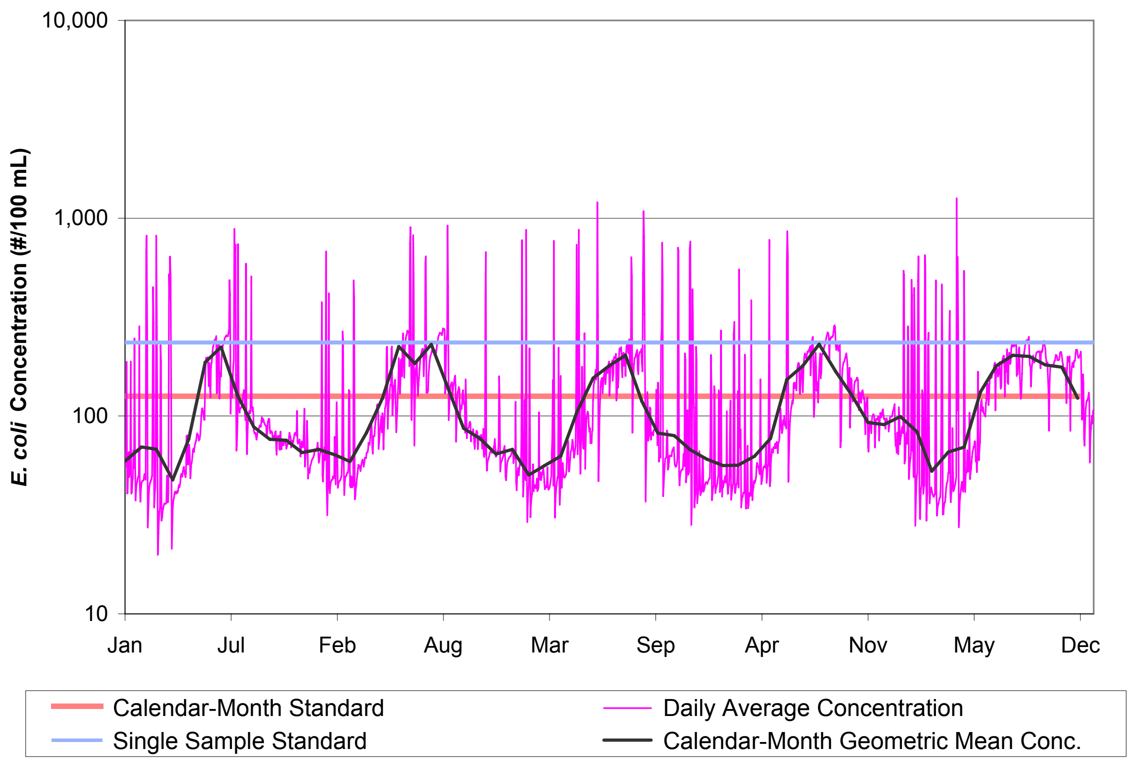

Figure 7.3. Simulated *E. coli* concentrations with the two bacteria standards for the Stage 1 implementation scenario for Upper Pigg River.

7.2.4. Stage 1 Scenario for 'Leesville Lake'-Pigg River

There was one successful scenario for the LL-Pigg River watershed (Table 7.4). This scenario incorporates the reductions specified in Sections 7.2.1-7.2.3 applied to the appropriate areas of the watershed; the reductions in Table 7.4 apply only to the portion of LL-Pigg River not in Snow Creek, Story

Creek, or Upper Pigg River. The Stage 1 implementation goal for LL-Pigg River can be reached with a 10% reduction in contributions from livestock direct deposit and a 100% reduction in contributions from straight pipes. *E. coli* concentrations resulting from application of the fecal coliform to *E. coli* translator equation to the Stage 1 fecal coliform concentrations are presented graphically in Figure 7.4.

Table 7.4. Allocation scenario for Stage 1 TMDL implementation for LL-Pigg River.

Single Sample Standard Percent Violation	Required Fecal Coliform Loading Reductions to Meet the Stage 1 Goal, %*					
	Livestock DD	Loads from Cropland	Loads from Pasture	Wildlife DD	Straight Pipes	Loads from Residential
10	10	0	0	0	100	0

*Reductions in this table apply only to the portion of LL-Pigg River not in Snow Creek, Story Creek, or Upper Pigg River; reductions for those areas are presented in Table 7.1, Table 7.2, and Table 7.3, respectively

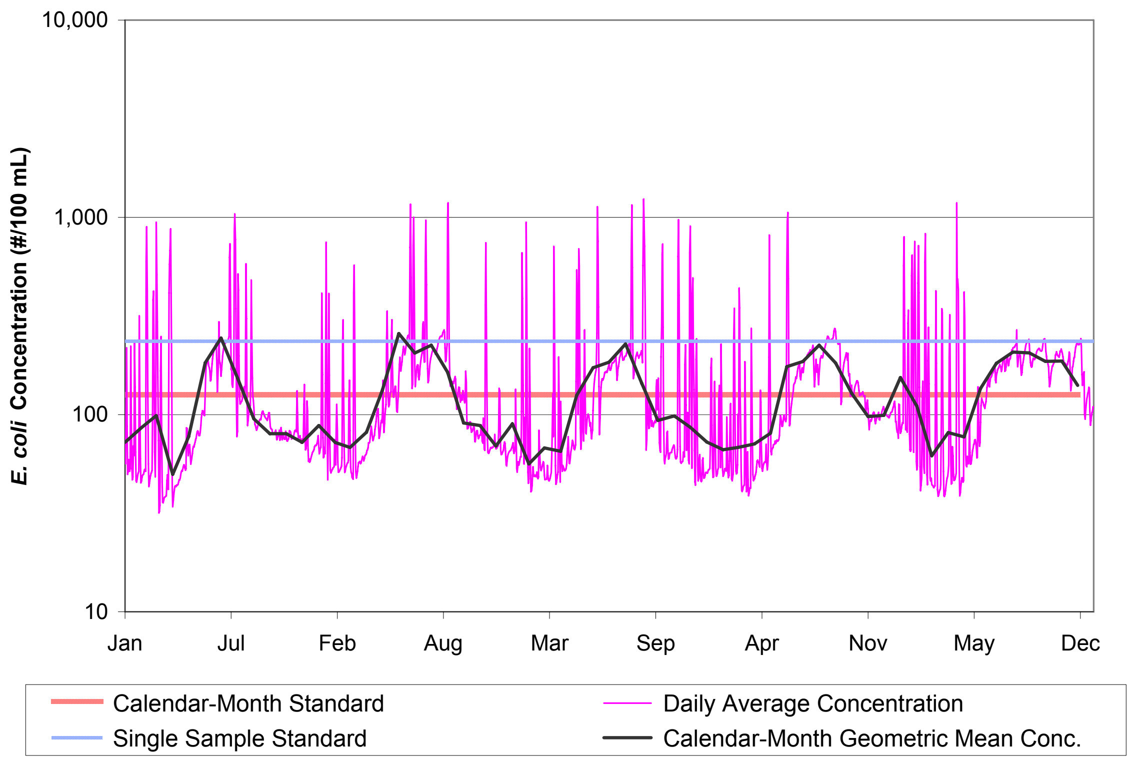

Figure 7.4. Simulated *E. coli* concentrations with the two bacteria standards for the Stage 1 implementation scenario for LL-Pigg River.

7.2.5. Stage 1 Scenario for Old Womans Creek

There was one successful scenario for the Old Womans Creek watershed (Table 7.5). Due to the high contributions from wildlife direct deposit (Table 6.24, Table 6.27), all that can be done with this scenario is to eliminate the requirements for wildlife direct deposit reductions. The non-wildlife reductions in Table 7.5 match those called for in the TMDL scenario. *E. coli* concentrations resulting from application of the fecal coliform to *E. coli* translator equation to the Stage 1 fecal coliform concentrations are presented graphically in Figure 7.5.

Table 7.5. Allocation scenario for Stage 1 TMDL implementation for Old Womans Creek.

Single Sample Standard Percent Violation	Required Fecal Coliform Loading Reductions to Meet the Stage 1 Goal, %				
	Livestock DD	Loads from Cropland	Loads from Pasture	Wildlife DD	Loads from Residential
9	100	0	90	0	85

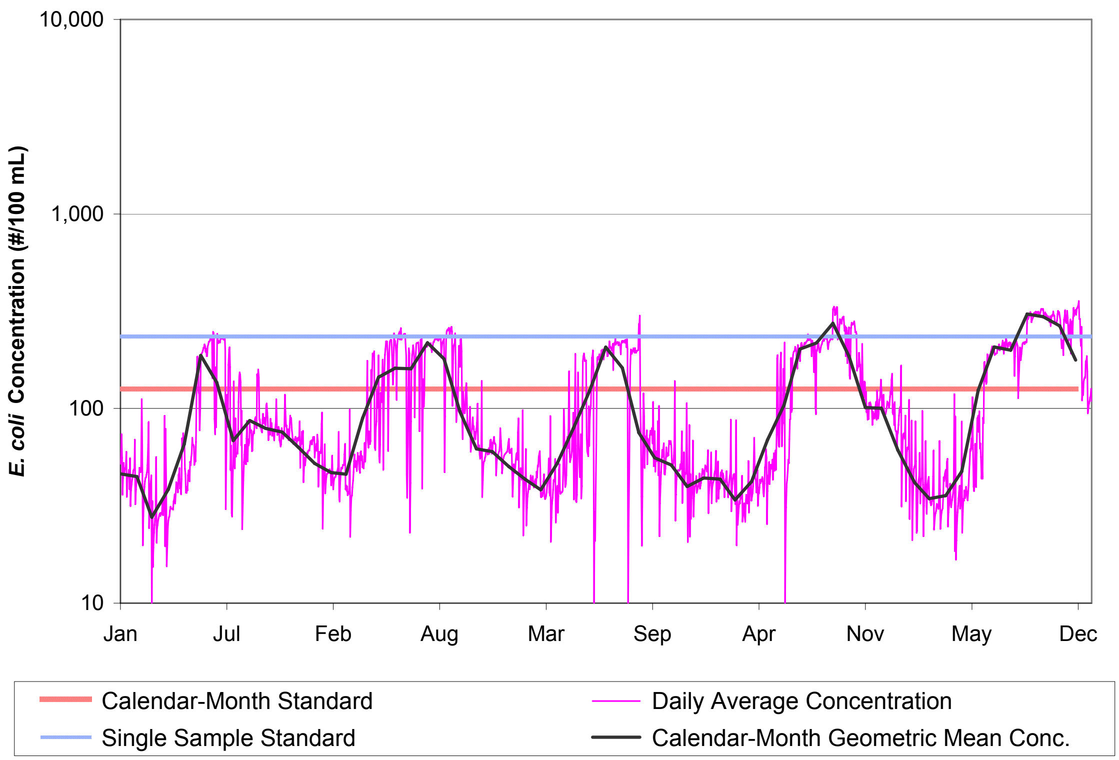

Figure 7.5. Simulated *E. coli* concentrations with the two bacteria standards for the Stage 1 implementation scenario for Old Womans Creek.

7.3. Link to Ongoing Restoration Efforts

Implementation of this TMDL will contribute to on-going water quality improvement efforts aimed at restoring water quality in the Pigg River, Snow Creek, Story Creek, and Old Womans Creek watersheds.

- Franklin County is currently developing a new Comprehensive Plan; Pittsylvania County will start developing a Comprehensive Plan in the near future. Given the timing of the TMDL, this is a good opportunity to consider the water quality effects of ongoing development in the TMDL watersheds as the counties plan for the future.
- Franklin County is developing a 63-mile long ‘blueway’ on Pigg River. Part of the blueway project involves posting interpretive signs to inform citizens about water quality in Waid Park.
- The Soil and Water Conservation Districts are active in aiding local farmers in the selection and implementation of BMPs.

7.4. Reasonable Assurance for Implementation

7.4.1. Follow-up Monitoring

Following the development of the TMDL, the Department of Environmental Quality (DEQ) will make every effort to continue to monitor the impaired stream in accordance with its ambient monitoring program. DEQ’s Ambient Watershed Monitoring Plan for conventional pollutants calls for watershed monitoring to take place on a rotating basis, bi-monthly for two consecutive years of a six-year cycle. In accordance with DEQ Guidance Memo No. 03-2004, during periods of reduced resources, monitoring can temporarily discontinue until the TMDL staff determines that implementation measures to address the source(s) of impairments are being installed. Monitoring can resume at the start of the following fiscal year, next scheduled monitoring station rotation, or where deemed necessary by the regional office or TMDL staff, as a new special study.

The purpose, location, parameters, frequency, and duration of the monitoring will be determined by the DEQ staff, in cooperation with DCR staff, the Implementation Plan Steering Committee, and local stakeholders. Whenever possible, the location of the follow-up monitoring station(s) will be the same as the listing station. At a minimum, the monitoring station must be representative of the original impaired segment. The details of the follow-up monitoring will be outlined in the Annual Water Monitoring Plan prepared by each DEQ Regional Office. Other agency personnel, watershed stakeholders, etc. may provide input on the Annual Water Monitoring Plan. These recommendations must be made to the DEQ regional TMDL coordinator by September 30 of each year.

DEQ staff, in cooperation with DCR staff, the Implementation Plan Steering Committee, and local stakeholders, will continue to use data from the ambient monitoring stations to evaluate reductions in pollutants ("water quality milestones" as established in the Implementation Plan), the effectiveness of the TMDL in attaining and maintaining water quality standards, and the success of implementation efforts. Recommendations may then be made, when necessary, to target implementation efforts in specific areas and continue or discontinue monitoring at follow-up stations.

In some cases, watersheds will require monitoring above and beyond what is included in DEQ's standard monitoring plan. Ancillary monitoring by citizens, watershed groups, local government, or universities is an option that may be used in such cases. An effort should be made to ensure that ancillary monitoring follows established QA/QC guidelines in order to maximize compatibility with DEQ monitoring data. In instances where citizens' monitoring data are not available and additional monitoring is needed to assess the effectiveness of targeting efforts, TMDL staff may request of the monitoring managers in each regional office an increase in the number of stations or monitor existing stations at a higher frequency in the watershed. The additional monitoring beyond the original bimonthly single station monitoring will be contingent on staff resources and available laboratory budget. More information on citizen monitoring in Virginia and QA/QC guidelines is available at http://www.deq.virginia.gov/cmonitor/.

To demonstrate that the watershed is meeting water quality standards in watersheds where corrective actions have taken place (whether or not a TMDL or TMDL Implementation Plan has been completed), DEQ must meet the minimum data requirements from the original listing station or a station representative of the originally listed segment. The minimum data requirement for conventional pollutants (bacteria, dissolved oxygen, etc) is bimonthly monitoring for two consecutive years. For biological monitoring, the minimum requirement is two consecutive samples (one in the spring and one in the fall) in a one year period.

7.4.2. Regulatory Framework

While section 303(d) of the Clean Water Act and current EPA regulations do not require the development of TMDL implementation plans as part of the TMDL process, they do require reasonable assurance that the load and wasteload allocations can and will be implemented. EPA also requires that all new or revised National Pollutant Discharge Elimination System (NPDES) permits must be consistent with the TMDL WLA pursuant to 40 CFR §122.44 (d)(1)(vii)(B). All such permits should be submitted to EPA for review.

Additionally, Virginia's 1997 Water Quality Monitoring, Information and Restoration Act (WQMIRA) directs the State Water Control Board to "develop and implement a plan to achieve fully supporting status for impaired waters" (Section 62.1-44.19.7). WQMIRA also establishes that the implementation plan shall include the date of expected achievement of water quality objectives, measurable goals, corrective actions necessary and the associated costs, benefits and environmental impacts of addressing the impairments. EPA outlines the minimum elements of an approvable implementation plan in its 1999 "Guidance for Water Quality-Based Decisions: The TMDL Process." The listed elements include implementation actions/management measures, timelines, legal or regulatory controls, time required to attain water quality standards, monitoring plans and milestones for attaining water quality standards.

For the implementation of the WLA component of the TMDL, the Commonwealth intends to utilize the Virginia NPDES (VPDES) program, which typically includes consideration of the WQMIRA requirements during the permitting process. Requirements of the permit process should not be duplicated in the TMDL process, and with the exception of stormwater related permits, permitted sources are not usually addressed during the development of a TMDL implementation plan.

For the implementation of the TMDL's LA component, a TMDL implementation plan addressing at a minimum the WQMIRA requirements will be developed. An exception are the municipal separate storm sewer systems (MS4s) which are both covered by NPDES permits and expected to be included in TMDL implementation plans, as described in the stormwater permit section below.

Watershed stakeholders will have opportunities to provide input and to participate in the development of the implementation plan. Regional and local offices of DEQ, DCR, and other cooperating agencies are technical resources to assist in this endeavor.

In response to a Memorandum of Understanding (MOU) between EPA and DEQ, DEQ also submitted a draft Continuous Planning Process to EPA in which DEQ commits to regularly updating the Water Quality Management Plans (WQMPs). Thus, the WQMPs will be, among other things, the repository for all TMDLs and TMDL implementation plans developed within a river basin.

DEQ staff will present both EPA-approved TMDLs and TMDL implementation plans to the State Water Control Board for inclusion in the appropriate WQMP, in accordance with the Clean Water Act's Section 303(e) and Virginia's Public Participation Guidelines for Water Quality Management Planning.

DEQ staff will also request that the SWCB adopt TMDL WLAs as part of the Water Quality Management Planning Regulation (9VAC 25-720), except in those cases when permit limitations are equivalent to numeric criteria contained in the Virginia Water Quality Standards, such as is the case for bacteria. This regulatory action is in accordance with §2.2-4006A.4.c and §2.2-4006B of the Code of Virginia. SWCB actions relating to water quality management planning are described in the public participation guidelines referenced above and can be found on DEQ’s web site under http://www.deq.state.va.us/tmdl/pdf/ppp.pdf.

7.4.3. Stormwater Permits

DEQ and DCR coordinate separate State programs that regulate the management of pollutants carried by storm water runoff. DEQ regulates storm water discharges associated with "industrial activities", while DCR regulates storm water discharges from construction sites, and from municipal separate storm sewer systems (MS4s).

EPA approved DCR's VPDES storm water program on December 30, 2004. DCR's regulations became effective on January 29, 2005. DEQ is no longer the regulatory agency responsible for administration and enforcement of the VPDES MS4 and construction storm water permitting programs. More information is available on DCR's web site through the following link: http://www.dcr.virginia.gov/sw/vsmp.

It is the intention of the Commonwealth that the TMDL will be implemented using existing regulations and programs. One of these regulations is DCR’s Virginia Stormwater Management Program (VSMP) Permit Regulation (4 VAC 50-60-10 et. seq). Section 4VAC 50-60-380 describes the requirements for stormwater discharges. Also, federal regulations state in 40 CFR §122.44(k) that NPDES permit conditions may consist of “Best management practices to control or abate the discharge of pollutants when:…(2) Numeric effluent limitations are infeasible,…”.

For MS4/VSMP general permits, the Commonwealth expects the permittee to specifically address the TMDL wasteload allocations for stormwater through the implementation of programmatic BMPs. BMP effectiveness would be determined through ambient in-stream monitoring. This is in accordance with recent EPA guidance (EPA Memorandum on TMDLs and Stormwater Permits, dated November 22, 2002). If future monitoring indicates no improvement in stream water quality, the permit could require the MS4 to expand or better tailor its stormwater management program to achieve the TMDL wasteload allocation.

However, only failing to implement the programmatic BMPs identified in the modified stormwater management program would be considered a violation of the permit. DEQ acknowledges that it may not be possible to meet the existing water quality standard because of the wildlife issue associated with a number of bacteria TMDLs (see section 7.4.5 below). At some future time, it may therefore become necessary to investigate the stream's use designation and adjust the water quality criteria through a Use Attainability Analysis. Any changes to the TMDL resulting from water quality standards change on Pigg River, Snow Creek, Story Creek, or Old Womans Creek would be reflected in the permit.

Wasteload allocations for stormwater discharges from storm sewer systems covered by a MS4 permit will be addressed in TMDL implementation plans. An implementation plan will identify types of corrective actions and strategies to obtain the wasteload allocation for the pollutant causing the water quality impairment. Permittees need to participate in the development of TMDL implementation plans since recommendations from the process may result in modifications to the stormwater management plan in order to meet the TMDL.

Additional information on Virginia's Stormwater Management program and a downloadable menu of Best Management Practices and Measurable Goals Guidance can be found at http://www.dcr.virginia.gov/sw/stormwat.htm.

7.4.4. Implementation Funding Sources

Cooperating agencies, organizations and stakeholders must identify potential funding sources available for implementation during the development of the implementation plan in accordance with the "Virginia Guidance Manual for Total Maximum Daily Load Implementation Plans". Potential sources for implementation may include the U.S. Department of Agriculture's Conservation Reserve Enhancement and Environmental Quality Incentive Programs, EPA Section 319 funds, the Virginia State Revolving Loan Program, Virginia Agricultural Best Management Practices Cost-Share Programs, the Virginia Water Quality Improvement Fund, tax credits and landowner contributions. The TMDL Implementation Plan Guidance Manual contains additional information on funding sources, as well as government agencies that might support implementation efforts and suggestions for integrating TMDL implementation with other watershed planning efforts.

7.4.5. Attainability of Primary Contact Recreation Use

In some streams for which TMDLs have been developed (including Pigg River and Old Womans Creek), water quality modeling indicates that even after removal of all bacteria sources (other than wildlife), the stream will not attain standards under all flow regimes at all times. These streams may not be able to attain standards without some reduction in wildlife load.

With respect to these potential reductions in bacteria loads attributed to wildlife, Virginia and EPA are not proposing the elimination of wildlife to allow for the attainment of water quality standards. However, if bacteria levels remain high and localized overabundant populations of wildlife are identified as the source, then measures to reduce such populations may be an option if undertaken in consultation with the Department of Game and Inland Fisheries (DGIF) or the United States Fish and Wildlife Service (USFWS). Additional information on DGIF's wildlife programs can be found at http://www.dgif.virginia.gov/hunting/va_game_wildlife/. While managing such overpopulations of wildlife remains as an option to local stakeholders, the reduction of wildlife or changing a natural background condition is not the intended goal of a TMDL.

To address the overall issue of attainability of the primary contact criteria, Virginia proposed during its latest triennial water quality standards review a new "secondary contact" category for protecting the recreational use in state waters. On March 25, 2003, the Virginia State Water Control Board adopted criteria for "secondary contact recreation" which means "a water-based form of recreation, the practice of which has a low probability for total body immersion or ingestion of waters (examples include but are not limited to wading, boating and fishing)". These new criteria became effective on February 12, 2004 and can be found at http://www.deq.virginia.gov/wqs/rule.html.

In order for the new criteria to apply to a specific stream segment, the primary contact recreational use must be removed. To remove a designated use, the state must demonstrate 1) that the use is not an existing use, 2) that downstream uses are protected, and 3) that the source of contamination is natural and uncontrollable by effluent limitations and by implementing cost-effective and reasonable best management practices for nonpoint source control (9 VAC 25-260-10). This and other information is collected through a special study called a Use Attainability Analysis (UAA). All site-specific criteria or designated use changes must be adopted as amendments to the water quality standards regulations. Watershed stakeholders and EPA will be able to provide comment during this process. Additional information can be obtained at http://www.deq.virginia.gov/wqs/documents/WQS06.pdf.

The process to address potentially unattainable reductions based on the above is as follows: First is the development of a stage 1 scenario such as those presented previously in this chapter. The pollutant reductions in the stage 1 scenario are targeted primarily at the controllable, anthropogenic bacteria sources identified in the TMDL, setting aside control strategies for wildlife except for cases of nuisance populations. During the implementation of the stage 1 scenario, all controllable sources would be reduced to the maximum extent practicable using the iterative approach described in Section 7.1 above. DEQ will re-assess water quality in the stream during and subsequent to the implementation of the stage 1 scenario to determine if the water quality standard is attained. This effort will also evaluate if the modeling assumptions were correct. If water quality standards are not being met, and no additional cost-effective and reasonable best management practices can be identified, a UAA may be initiated with the goal of re-designating the stream for secondary contact recreation.

Chapter 8: Public Participation

A kick-off meeting was held on May 25, 2005 at the Blue Ridge Soil and Water Conservation District office in Rocky Mount, Virginia. This meeting notified key local agency personnel of the beginning of the TMDL study and solicited their input on preliminary watershed characterization estimates. Approximately 10 people attended the meeting.

Two ‘first public meetings’ were held. The first was held on August 16, 2005 at the W. E. Skelton Conference Center (4-H Center) in Wirtz, Virginia; approximately 16 people attended this meeting (including 5 personnel from DEQ, DCR, or Virginia Tech). Due to the low turnout at this meeting, a second first public meeting was held on October 27, 2005 at Sontag Elementary School in Rocky Mount, Virginia; approximately 20 people attended this meeting, including three personnel from DEQ or Virginia Tech. During both meetings, an overview of TMDLs and the TMDL development process was presented and comments were solicited on preliminary estimates of animal populations.

The first Technical Advisory Committee meeting was held on January 18, 2006 at the Gretna Public Library in Gretna, Virginia. The purpose of this meeting was to finalize the watershed characterization information prior to the beginning of water quality modeling. Approximately 9 people attended the meeting, including 2 people from DEQ/Virginia Tech. Stakeholders at this meeting provided a number of contacts to pursue for more information; these contacts were called on the phone or visited in person to acquire detailed input for the modeling process.

The second Technical Advisory Committee meeting was held on February 15, 2006 at the Gretna Public Library in Gretna, Virginia. The calibration and validation results from water quality modeling were presented at this meeting for stakeholder approval. Preliminary allocation scenarios were also presented, and stakeholders provided feedback regarding the desired distribution of reductions for final allocation scenarios. Approximately 7 people attended this meeting, including 3 people from DEQ/Virginia Tech.

The final public meeting was held on March 9, 2006 at Sontag Elementary School in Rocky Mount, Virginia. Final allocation and stage 1 scenarios were presented at this meeting. Approximately XX people attended this meeting.

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Appendix A: Glossary of Terms

Allocation

That portion of a receiving water's loading capacity that is attributed to one of its existing or future pollution sources (nonpoint or point) or to natural background sources.

Allocation Scenario

A proposed series of point and nonpoint source allocations (loadings from different sources), which are being considered to meet a water quality planning goal.

ARA (Antibiotic Resistance Analysis)

A bacterial source tracking technique that uses the expected varying antibiotic resistance of bacteria from different sources to identify the contributors of fecal bacteria. Bacteria from humans are expected to have the highest antibiotic resistance, while domestic and wildlife animal sources are expected to have lower antibiotic resistance (Hagedorn, 2006).

Background levels

Levels representing the chemical, physical, and biological conditions that would result from natural geomorphological processes such as weathering and dissolution.

BASINS (Better Assessment Science Integrating Point and Nonpoint Sources)

A computer-run tool that contains an assessment and planning component that allows users to organize and display geographic information for selected watersheds. It also contains a modeling component to examine impacts of pollutant loadings from point and nonpoint sources and to characterize the overall condition of specific watersheds.

Best Management Practices (BMP)

Methods, measures, or practices that are determined to be reasonable and cost-effective means for a land owner to meet certain, generally nonpoint source, pollution control needs. BMPs include structural and nonstructural controls and operation and maintenance procedures.

Bacteria Source Tracking

A collection of scientific methods used to track sources of fecal coliform.

Calibration

The process of adjusting model parameters within physically defensible ranges until the resulting predictions give a best possible good fit to observed data.

Die-off (of fecal coliform)

Reduction in the fecal coliform population due to predation by other bacteria as well as by adverse environmental conditions (e.g., UV radiation, pH).

Direct nonpoint sources

Sources of pollution that are defined statutorily (by law) as nonpoint sources that are represented in the model as point source loadings due to limitations of the model. Examples include: direct deposits of fecal material to streams from livestock and wildlife.

Failing septic system

Septic systems in which drain fields have failed such that effluent (wastewater) that is supposed to percolate into the soil, now rises to the surface and ponds on the surface where it can flow over the soil surface to streams or contribute pollutants to the surface where they can be lost during storm runoff events.

Fecal coliform

A type of bacteria found in the feces of various warm-blooded animals that is used as indicator of the possible presence of pathogenic (disease causing) organisms. *E. coli* bacteria are a subset of this group found to more closely correlate with human health problems.

Geometric mean

The geometric mean is simply the nth root of the product of n values. Using the geometric mean lessens the significance of a few extreme values (extremely high or low values). In practical terms, this means that if you have just a few bad samples, their weight is lessened.

Mathematically the geometric mean, $\overline{x}_g$, is expressed as:

$$\overline{x}_g = \sqrt[n]{x_1 \cdot x_2 \cdot x_3 \ldots \cdot x_n}$$

where n is the number of samples, and x_i is the value of sample i.

HSPF (Hydrological Simulation Program-Fortran)

A computer-based model that calculates runoff, sediment yield, and fate and transport of various pollutants to the stream. The model was developed under the direction of the U.S. Environmental Protection Agency (EPA).

Hydrology

The study of the distribution, properties, and effects of water on the earth's surface, in the soil and underlying rocks, and in the atmosphere.

Instantaneous or Single Sample criterion

The instantaneous criterion or instantaneous water quality standard is the value of the water quality standard that should not be exceeded at any time. For example, the Virginia instantaneous water quality standard for fecal coliform is 400 cfu/100 mL. If this value is exceeded at any time, the water body is in violation of the state water quality standard.

Load allocation (LA)

The portion of a receiving water's loading capacity that is attributed either to one of its existing or future nonpoint sources of pollution or to natural background.

Margin of Safety (MOS)

A required component of the TMDL that accounts for the uncertainty about the relationship between the pollutant loads and the quality of the receiving waterbody. The MOS is normally incorporated into the conservative assumptions used to develop TMDLs (generally within the calculations or models). The MOS may also be assigned explicitly, as was done in this study, to ensure that the water quality standard is not violated.

Model

Mathematical representation of hydrologic and water quality processes. Effects of Land use, slope, soil characteristics, and management practices are included.

Nonpoint source

Pollution that is not released through pipes but rather originates from multiple sources over a relatively large area. Nonpoint sources can be divided into source activities related to either land or water use including failing septic tanks, improper animal-keeping practices, forest practices, and urban and rural runoff.

Pathogen

Disease-causing agent, especially microorganisms such as bacteria, protozoa, and viruses.

Point source

Pollutant loads discharged at a specific location from pipes, outfalls, and conveyance channels from either municipal wastewater treatment plants or industrial waste treatment facilities. Point sources can also include pollutant loads contributed by tributaries to the main receiving water stream or river.

Pollution

Generally, the presence of matter or energy whose nature, location, or quantity produces undesired environmental effects. Under the Clean Water Act for example, the term is defined as the man-made or man-induced alteration of the physical, biological, chemical, and radiological integrity of water.

Reach

Segment of a stream or river.

Runoff

That part of rainfall or snowmelt that runs off the land into streams or other surface water. It can carry pollutants from the air and land into receiving waters.

Septic system

An on-site system designed to treat and dispose of domestic sewage. A typical septic system consists of a tank that receives liquid and solid wastes from a residence or business and a drainfield or subsurface absorption system consisting of a series of tile or percolation lines for disposal of the liquid effluent. Solids (sludge) that remain after decomposition by bacteria in the tank must be pumped out periodically.

Simulation

The use of mathematical models to approximate the observed behavior of a natural water system in response to a specific known set of input and forcing conditions. Models that have been validated, or verified, are then used to predict the response of a natural water system to changes in the input or forcing conditions.

Straight pipe

Delivers wastewater directly from a building, e.g., house, milking parlor, to a stream, pond, lake, or river.

Total Maximum Daily Load (TMDL)

The sum of the individual wasteload allocations (WLA's) for point sources, load allocations (LA's) for nonpoint sources and natural background, plus a margin of safety (MOS). TMDLs can be expressed in terms of mass per time, toxicity, or other appropriate measures that relate to a state's water quality standard.

Urban Runoff

Surface runoff originating from an urban drainage area including streets, parking lots, and rooftops.

Validation (of a model)

Process of determining how well the mathematical model's computer representation describes the actual behavior of the physical process under investigation.

Wasteload allocation (WLA)

The portion of a receiving water's loading capacity that is allocated to one of its existing or future point sources of pollution. WLAs constitute a type of water quality-based effluent limitation.

Water quality standard

Law or regulation that consists of the beneficial designated use or uses of a water body, the numeric and narrative water quality criteria that are necessary to protect the use or uses of that particular water body, and an anti-degradation statement.

Watershed

A drainage area or basin in which all land and water areas drain or flow toward a central collector such as a stream, river, or lake at a lower elevation.

For more definitions, see the Virginia Cooperative Extension publications available online:

Glossary of Water-Related Terms. Publication 442-758.

http://www.ext.vt.edu/pubs/bse/442-758/442-758.html

and

TMDLs (Total Maximum Daily Loads) - Terms and Definitions. Publication 442-550.

http://www.ext.vt.edu/pubs/bse/442-550/442-550.html

Appendix B: Sample Calculation of Cattle (Sub-watershed 22 of the Pigg River Basin)

Sample Calculation: Distribution of Cattle

(Sub-watershed 22 during October)

(Note: Due to rounding, the numbers may not add up.)

There are 360 beef cows in sub-watershed 22.

1. During January, beef cattle in sub-watershed 22 are confined 0.7% of the time (Table 4.7).

   Beef cattle in confinement = 360 * 0.7% = 2.52

2. When not confined, cattle are on pasture or in the stream.

   Beef cattle on pasture and in the stream = 360 – 2.52 = 357.48

3. Sixty percent of beef cows in subwatershed 22 have stream access. Hence beef cattle with stream access are calculated as:

   Beef cattle on pastures with stream access = 357.48 * 60% = 214.49

4. Beef cattle in and around the stream are calculated using the numbers in Step 3 and the number of hours cattle spend in the stream in January (Table 4.7) as:

   Beef cattle in and around streams = 214.49 * 0.5/24 = 4.47

5. Number of cattle defecating in the stream is calculated by multiplying the number of cattle in and around the stream by 30% (Section 4.2.1):

   Beef cattle defecating in streams = 4.47 * 30% = 1.34

6. After calculating the number of cattle defecating in the stream, the number of cattle defecating on the pasture is calculated by subtracting the number of cattle defecating in the stream (Step 5) from the number of cattle in pasture and stream (Step 2):

   Beef cattle defecating on pasture = 357.48 -1.34 = 356.14

Now, obviously there are not fractions of cows standing and defecating in the stream. This number (1.34) represents the fraction of fecal coliform produced in one day by one cow that will be deposited in the stream.

Appendix C: Die-off of Fecal Coliform During Storage

Die-off of Fecal Coliform During Storage

The following procedure was used to calculate amount of fecal coliform produced in confinement in dairy manure applied to cropland and pasture. All calculations were performed on spreadsheet for each sub watershed with dairy operations in a watershed.

1. It was assumed based on previous producer surveys in previous TMDLs that 15% of the dairy farms had dairy manure storage for less than 30 days; 10% of the dairy farms had storage capacities of 60 days, while the remaining operations had 180-day storage capacity. Using a decay rate of 0.375 for liquid dairy manure, the die-off of fecal coliform in different storage capacities at the ends of the respective storage periods were calculated using Eq. [5.1]. Based on the fractions of different storage capacities, a weighted average die-off was calculated for all dairy manure.
2. Based on fecal coliform die-off, the surviving fraction of fecal coliform at the end of storage period was estimated to be 0.0078 in dairy manure.
3. The annual production of fecal coliform based on 'as-excreted' values was calculated for dairy manure.
4. The annual fecal coliform production from dairy manure was multiplied by the fraction of surviving fecal coliform to obtain the amount of fecal coliform that was available for land application on annual basis. For monthly application, the annual figure was multiplied by the fraction of dairy applied during that month based on the application schedule given in Table 4.11 and Table 4.12.

Appendix D: Weather Data Preparation

Weather Data Preparation

Introduction

A weather data file for providing the weather data inputs into the HSPF Model was created for the period January 1984 through December 2002 using the WDMUtil. After the commencement of modeling, this period was extended through August 2005 to allow the use of more recently collected data; this extension followed the same procedure outlined in this appendix for the 1984-2002 period. Raw data required for creating the weather data file included hourly precipitation (in.), average daily temperatures (maximum, minimum, and dew point) (°F), average daily wind speed (mi/hr), total daily solar radiation (Langleys), and percent sun. The primary data source was the National Climatic Data Center's (NCDC) Cooperative Weather Station at Rocky Mount, Franklin County, Virginia, which was located within the Pigg River watershed. Data from three other NCDC stations were also used. The raw data required varying amounts of preprocessing within WDMUtil to obtain the following hourly values: precipitation (PREC) (in), air temperature (ATEM) (°F), dew point temperature (DEWP) (°F), solar radiation (SOLR) (Langleys), wind speed (WIND) (mi/hr), potential evapotranspiration (PEVT) (in), potential evaporation (EVAP) (in), and cloud cover (CLOU) (tenths, range 0-10). The final WDM file contains these hourly datasets.

Raw data collection and processing

Weather data were obtained from the NCDC's weather stations in Rocky Mount, VA (447338, Lat./Long. 36°59'N/79°54'W, elevation 400.8 ft); Chatham, VA (441614, Lat./Long. 36°49'N/79°25'W, elevation 195.1 ft); Roanoke Regional Airport, VA (447285, Lat./Long. 37°19'N/79°58'W, elevation 350.2 ft), and Lynchburg Airport, VA (445120, Lat./Long. 37°20'N/79°12'W, elevation 286.5 ft). While deciding on the period of record for the weather WDM file, availability of flow and water quality data was considered in addition to the availability and quality of weather data. Data collection for many of the parameters did not being until 1984, which set the starting point of the period of record. Percent sun data were available only through July 1996. The majority of the water quality data were collected from 1990-present. In order to make the best use of the available water quality data, the period of record was chosen to be 1984-2002. There are 6,940 days within this period. Substitutions for missing data are described below. The procedures used to process the raw data to obtain finished data required for input to HSPF are also described in the following sections.

1. <u>Hourly Precipitation</u>
   Hourly precipitation (HPCP) data were downloaded from NCDC's web site for Rocky Mount and Chatham for the entire 1984-2002 period. Of the 166,560 possible hourly values in this period, 48,034 values were missing. The Rocky Mount record was patched with the hourly recorded precipitation at the Chatham station; the combination still left 29,546 hourly values missing. For the hourly events that were still missing, the following procedure was followed to patch with the observed daily precipitation at Rocky Mount (PRCP):
   a. For precipitation depths less than or equal to 0.2 in, the entire daily precipitation event as was assumed to have occurred during the 6:00-7:00 pm hour of the previous day.
   b. For precipitation depths greater than 0.2 in and 3 or fewer hours of data missing, the difference between the total daily precipitation and the recorded hourly precipitation was evenly divided between the missing hours.
   c. For precipitation depths greater than 0.2 in and more than three hours of data missing, the daily precipitation total was divided into three even increments and assigned to the 3:00, 4:00, and 5:00 pm hours of the previous day.

   The resulting file was imported into WDMUtil and given the constituent label "PREC."

2. <u>Temperature</u>
   Separate daily maximum temperature (TMAX) and daily minimum temperature (TMIN) files were downloaded from the NCDC website. The TMAX dataset was missing 238 days of data; the TMIN dataset was missing 269 days of data. Data from the Chatham station were used to fill in the missing days. Daily dew point temperature (DPTP) was taken from the Roanoke Regional Airport station, the closest station that recorded dew point temperature. These data had units of tenths of degrees Fahrenheit and were divided by a factor of 10 prior to use in the WDM file. The *disaggregate temperature* function in WDMUtil was used to create an hourly average temperature file (ATEM). The *disaggregate dewpoint*

temperature function in WDMUtil was used to create an hourly dewpoint temperature file (DEWP).

3. Average Daily Wind Speed
Average daily wind speed (AWND) was not recorded at the Rocky Mount station; therefore, average daily wind speed was obtained from the Roanoke Regional Airport. The units of the data were tenths of miles per hour; therefore, the timseries was divided by a factor of 10 prior to use in the WDM file. The *compute wind travel* function in WDMUtil was used to calculate the total wind travel in miles/day. Then the *disaggregate wind travel* function in WDMUtil was used to calculate the hourly wind speed throughout the day (WIND) using the distribution coefficients shown in **Error! Reference source not found.**.

Table D.1. Hourly Distribution Coefficients for Wind Speed.

Hour	12	1	2	3	4	5	6	7	8	9	10	11
AM	0.035	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.035	0.037	0.041	0.046
PM	0.05	0.053	0.054	0.058	0.057	0.056	0.05	0.043	0.04	0.038	0.036	0.036

4. Cloud cover and solar radiation
In the absence of daily cloud cover, percent sun (PSUN) can be used to estimate DCLO. DCLO is used by WDMUtil to estimate hourly cloud cover in tenths (CLOU) as well as solar radiation (SOLR) in Langleys. The closest weather station that recorded PSUN was Lynchburg Airport, and this data was used to develop the weather file. As previously mentioned, PSUN was only available at this station for the period January 1984-July 1996. It is the experience of the authors that the model is rather insensitive to the parameters derived from PSUN; therefore, to bridge the gap of missing data, values from August 1996-December 2002 were filled in by copying the values from August 1984-December 1990.

The *compute percent cloud cover* function in WDMUtil was used to calculate the daily percent cloud cover in tenths (DCLO) from PSUN. Because there is not a *disaggregate percent cloud cover* function available, the *disaggregate wind travel* function was used with hourly distribution coefficients all set to 1 to calculate the hourly percent cloud cover in tenths (CLOU).

The *compute solar radiation* function in WDMUtil was used to calculate the daily solar radiation in Langleys (DSOL) from DCLO and the Rocky Mount station latitude (36°59'N). The *disaggregate solar radiation* function was then used to calculate the hourly solar radiation (SOLR).

5. Evaporation/Evapotranspiration
Two types of evaporation/evapotranspiration are required for input to HSPF: potential evaporation from a reach or reservoir surface (EVAP), represented as Penman pan evaporation; and potential evapotranspiration

(PEVT), represented as Hamon potential evapotranspiration.

The *compute Penman pan evaporation* function in WDMUtil was used to calculate daily Penman pan evaporation (DEVP) from TMIN, TMAX, DPTP, TWND, and DSOL. Then the *disaggregate evapotranspiration* function was used to calculate EVAP from DEVP.

The *compute Hamon PET* function in WDMUtil was used to calculate daily potential evapotranspiration (DEVT) from TMIN, TMAX, the Rocky Mount station latitude (36°59'N), and monthly coefficients all equal to 0.005. Then the *disaggregate evapotranspiration* function was used to calculate PEVT from DEVT.

Summary of weather data preparation

The weather data were prepared for input to HSPF as described in the previous section. A summary of the NCDC input parameters, WDMUtil functions used, and final HSPF parameters is presented in Table D.2.

Table D.2. Weather parameters and processing in WDMUtil required for HSPF modeling.

NCDC Input Parameters	Intermediate Input	WDMUtil Functions	Intermediate Output	Final HSPF Parameter
HPCP	--	None	--	PREC
TMAX, TMIN	--	Disaggregate temperature	--	ATEM
DPTP	--	Disaggregate dewpoint temperature	--	DEWP
PSUN	--	Compute percent cloud cover	DCLO	--
	DCLO	Disaggregate wind travel[1]	--	CLOU
	DCLO	Compute solar radiation	DSOL	--
	DSOL	Disaggregate solar radiation	--	SOLR
AWND	--	Compute wind travel	TWND	--
	TWND	Disaggregate wind travel	--	WIND
TMAX, TMIN, DPTP	TWND, DSOL	Compute Penman pan evaporation	DEVP	--
	DEVP	Disaggregate evapotranspiration	--	EVAP
TMAX, TMIN	--	Compute Hamon PET	DEVT	--
	DEVT	Disaggregate evapotranspiration	--	PEVT

[1]all hourly coefficients set to 1

Appendix E: HSPF Parameters that Vary by Month or Land Use

Table E.1. PWAT-PARM2 parameters varying by land use and subwatershed.

Land Use	Parameter	Sub-watershed Number										
		1	2	3	4	5	6	7	8	9	10	11
Crop	INFILT	0.165	0.178	0.178	0.17	0.178	0.178	0.178	0.178	0.153	0.178	0.178
	LSUR	500	500	500	500	500	500	500	500	500	500	500
	SLSUR	0.0647	0.1401	0.106	0.0916	0.054	0.0532	0.06	0.1441	0.0771	0.0672	0.0623
Forest	INFILT	0.16	0.178	0.178	0.167	0.178	0.178	0.178	0.178	0.129	0.178	0.178
	LSUR	242	390	500	344	500	425	333	416	308	358	240
	SLSUR	0.0983	0.1075	0.1128	0.1105	0.0914	0.0692	0.0729	0.1071	0.0923	0.0979	0.1005
HDR	INFILT	n/a	n/a	n/a	n/a	n/a	n/a	0.178	n/a	0.178	0.178	0.178
	LSUR	n/a	n/a	n/a	n/a	n/a	n/a	500	n/a	500	262	500
	SLSUR	n/a	n/a	n/a	n/a	n/a	n/a	0.0454	n/a	0.0585	0.0103	0.0559
LDR	INFILT	0.166	0.178	0.178	0.172	0.178	0.178	0.178	0.178	0.125	0.178	0.178
	LSUR	179	500	500	500	500	497	500	500	500	500	500
	SLSUR	0.0951	0.0985	0.1442	0.1001	0.046	0.0747	0.0682	0.0418	0.0804	0.0633	0.0607
Pasture	INFILT	0.172	0.178	0.178	0.168	0.178	0.178	0.178	0.178	0.147	0.178	0.178
	LSUR	329	500	500	458	500	91	287	500	285	242	337
	SLSUR	0.0707	0.0954	0.0999	0.0871	0.0732	0.059	0.0692	0.0812	0.0737	0.063	0.0649

Table E.1. PWAT-PARM2 parameters varying by land use and sub-watershed (continued).

Land Use	Parameter	Sub-watershed Number											
		12	13	14	15	16	17	18	19	20	21	22	23
Crop	INFILT	0.178	0.172	0.164	0.135	0.178	0.178	0.178	0.177	0.178	0.178	0.18	0.178
	LSUR	500	500	500	500	500	500	482	500	500	500	500	500
	SLSUR	0.0824	0.0738	0.0722	0.0914	0.0744	0.0725	0.0884	0.0699	0.0846	0.095	0.1249	0.1504
Forest	INFILT	0.178	0.171	0.147	0.149	0.178	0.178	0.178	0.165	0.178	0.178	0.245	0.178
	LSUR	201	327	188	319	456	246	212	445	370	380	318	500
	SLSUR	0.1278	0.0795	0.1347	0.0958	0.0752	0.1132	0.1407	0.0926	0.0937	0.1143	0.2049	0.1366
HDR	INFILT	0.178	n/a	n/a	0.103	0.178	0.178	0.178	0.163	0.178	0.178	0.178	0.178
	LSUR	500	n/a	n/a	390	500	500	474	500	500	149	500	500
	SLSUR	0.0963	n/a	n/a	0.0905	0.0695	0.0799	0.1116	0.0728	0.0955	0.0893	0.0832	0.0969
LDR	INFILT	0.178	0.139	0.096	0.117	0.178	0.178	0.178	0.167	0.178	0.178	0.184	0.178
	LSUR	500	500	118	500	500	260	500	500	500	500	500	500
	SLSUR	0.1401	0.0543	0.1273	0.096	0.0886	0.0824	0.1163	0.0809	0.0677	0.0853	0.121	0.1141
Pasture	INFILT	0.178	0.177	0.15	0.137	0.178	0.178	0.163	0.178	0.178	0.178	0.193	0.178
	LSUR	114	351	297	246	231	214	129	500	148	291	374	500
	SLSUR	0.0831	0.0777	0.0826	0.0958	0.0709	0.0886	0.0947	0.0772	0.0888	0.0886	0.1369	0.1189

Table E.2. MON-INTERCEP (monthly CEPSC) - Monthly Interception Storage.

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Forest	0.1	0.1	0.13	0.16	0.18	0.3	0.3	0.3	0.19	0.14	0.12	0.1
HDR	0.09	0.09	0.09	0.09	0.09	0.11	0.11	0.11	0.09	0.09	0.09	0.09
LDR	0.09	0.09	0.09	0.09	0.09	0.11	0.11	0.11	0.09	0.09	0.09	0.09
Pasture	0.08	0.09	0.13	0.16	0.18	0.2	0.2	0.2	0.19	0.14	0.1	0.08
Crop	0.06	0.07	0.1	0.18	0.21	0.26	0.26	0.23	0.2	0.18	0.08	0.06

Table E.3. MON-UZSN - Monthly Upper Zone Nominal Storage.

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Forest	0.9	0.9	0.9	0.9	1	1	1	1	1	0.95	0.9	0.9
HDR	0.8	0.8	0.8	0.8	0.9	1	1	1	0.9	0.8	0.8	0.8
LDR	0.8	0.8	0.8	0.8	0.9	1	1	1	0.9	0.8	0.8	0.8
Pasture	0.8	0.8	0.8	0.8	0.9	1	1	1	1	0.8	0.8	0.8
Crop	0.35	0.35	0.35	0.4	0.5	0.9	0.9	0.9	0.8	0.6	0.4	0.35

Table E.4. MON-LZETP - Monthly Lower Zone Evapotranspiration Parameter.

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Forest	0.35	0.35	0.45	0.5	0.55	0.75	0.75	0.65	0.6	0.5	0.45	0.35
HDR	0.25	0.25	0.27	0.27	0.3	0.3	0.3	0.3	0.27	0.27	0.25	0.25
LDR	0.25	0.25	0.3	0.3	0.35	0.35	0.35	0.3	0.3	0.3	0.25	0.25
Pasture	0.25	0.35	0.45	0.5	0.55	0.75	0.75	0.65	0.6	0.5	0.4	0.25
Crop	0.25	0.35	0.45	0.5	0.55	0.75	0.75	0.65	0.6	0.5	0.4	0.25

Table E.5. MON-ACCUM Table for Pigg River – Monthly Accumulation Rate of Bacteria on the Soil Surface (cfu/ac/day).

Sub-watershed	Land Use	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	Crop	1.90E+07	1.90E+07	1.90E+07	1.90E+07	1.90E+07	1.90E+07	1.90E+07	1.90E+07	1.90E+07	1.90E+07	1.90E+07	1.90E+07
1	Pasture	2.60E+08	3.00E+08	3.10E+08	3.20E+08	3.20E+08	3.20E+08	3.30E+08	3.40E+08	3.50E+08	2.30E+08	2.40E+08	2.50E+08
1	LDR	1.90E+09	1.90E+09	1.90E+09	1.90E+09	1.90E+09	1.90E+09	1.90E+09	1.90E+09	1.90E+09	1.90E+09	1.90E+09	1.90E+09
1	Forest	9.20E+07	9.20E+07	6.90E+07	6.90E+07	6.90E+07	6.90E+07	6.90E+07	6.90E+07	9.20E+07	9.20E+07	9.20E+07	9.20E+07
2	Crop	1.70E+07	1.70E+07	1.70E+07	1.70E+07	1.70E+07	1.70E+07	1.70E+07	1.70E+07	1.70E+07	1.70E+07	1.70E+07	1.70E+07
2	Pasture	1.70E+07	1.70E+07	1.70E+07	1.70E+07	1.70E+07	1.70E+07	1.70E+07	1.70E+07	1.70E+07	1.70E+07	1.70E+07	1.70E+07
2	LDR	7.70E+09	7.70E+09	7.70E+09	7.70E+09	7.70E+09	7.70E+09	7.70E+09	7.70E+09	7.70E+09	7.70E+09	7.70E+09	7.70E+09
2	Forest	7.20E+07	7.20E+07	5.50E+07	5.50E+07	5.50E+07	5.50E+07	5.50E+07	5.50E+07	7.20E+07	7.20E+07	7.20E+07	7.20E+07
3	Crop	1.20E+08	1.30E+08	7.20E+08	6.60E+08	6.00E+08	1.80E+07	1.80E+07	1.80E+07	1.80E+07	6.20E+08	4.80E+08	1.20E+08
3	Pasture	6.30E+09	6.30E+09	7.80E+09	7.80E+09	7.80E+09	7.80E+09	7.80E+09	7.80E+09	7.80E+09	7.80E+09	7.80E+09	6.30E+09
3	LDR	3.20E+09	3.20E+09	3.20E+09	3.20E+09	3.20E+09	3.20E+09	3.20E+09	3.20E+09	3.20E+09	3.20E+09	3.20E+09	3.20E+09
3	Forest	1.00E+08	1.00E+08	7.40E+07	7.40E+07	7.40E+07	7.40E+07	7.40E+07	7.40E+07	1.00E+08	1.00E+08	1.00E+08	1.00E+08
4	Crop	1.80E+07	1.80E+07	1.80E+07	1.80E+07	1.80E+07	1.80E+07	1.80E+07	1.80E+07	1.80E+07	1.80E+07	1.80E+07	1.80E+07
4	Pasture	7.10E+08	8.40E+08	8.60E+08	8.80E+08	9.00E+08	9.20E+08	9.50E+08	9.70E+08	1.00E+09	6.20E+08	6.50E+08	6.80E+08
4	LDR	3.00E+09	3.00E+09	3.00E+09	3.00E+09	3.00E+09	3.00E+09	3.00E+09	3.00E+09	3.00E+09	3.00E+09	3.00E+09	3.00E+09
4	Forest	7.40E+07	7.40E+07	5.70E+07	5.70E+07	5.70E+07	5.70E+07	5.70E+07	5.70E+07	7.40E+07	7.40E+07	7.40E+07	7.40E+07
5	Crop	2.00E+07	2.00E+07	2.00E+07	2.00E+07	2.00E+07	2.00E+07	2.00E+07	2.00E+07	2.00E+07	2.00E+07	2.00E+07	2.00E+07
5	Pasture	1.50E+09	1.70E+09	1.80E+09	1.80E+09	1.90E+09	1.90E+09	2.00E+09	2.00E+09	2.10E+09	1.30E+09	1.40E+09	1.40E+09
5	LDR	2.20E+10	2.20E+10	2.20E+10	2.20E+10	2.20E+10	2.20E+10	2.20E+10	2.20E+10	2.20E+10	2.20E+10	2.20E+10	2.20E+10
5	Forest	6.60E+07	6.60E+07	5.20E+07	5.20E+07	5.20E+07	5.20E+07	5.20E+07	5.20E+07	6.60E+07	6.60E+07	6.60E+07	6.60E+07
6	Crop	1.80E+07	1.80E+07	1.80E+07	1.80E+07	1.80E+07	1.80E+07	1.80E+07	1.80E+07	1.80E+07	1.80E+07	1.80E+07	1.80E+07
6	Pasture	1.80E+07	1.80E+07	1.80E+07	1.80E+07	1.80E+07	1.80E+07	1.80E+07	1.80E+07	1.80E+07	1.80E+07	1.80E+07	1.80E+07
6	LDR	4.50E+09	4.50E+09	4.50E+09	4.50E+09	4.50E+09	4.50E+09	4.50E+09	4.50E+09	4.50E+09	4.50E+09	4.50E+09	4.50E+09
6	Forest	1.20E+08	1.20E+08	9.10E+07	9.10E+07	9.10E+07	9.10E+07	9.10E+07	9.10E+07	1.20E+08	1.20E+08	1.20E+08	1.20E+08
7	Crop	8.70E+07	9.30E+07	2.30E+08	2.00E+08	1.80E+08	1.70E+07	1.70E+07	1.70E+07	1.70E+07	1.60E+08	1.60E+08	8.70E+07
7	Pasture	1.50E+09	1.80E+09	1.80E+09	1.90E+09	1.90E+09	1.90E+09	2.00E+09	2.00E+09	2.10E+09	1.30E+09	1.40E+09	1.40E+09
7	LDR	3.00E+09	3.00E+09	3.00E+09	3.00E+09	3.00E+09	3.00E+09	3.00E+09	3.00E+09	3.00E+09	3.00E+09	3.00E+09	3.00E+09
7	HDR	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
7	Forest	1.10E+08	1.10E+08	7.80E+07	7.80E+07	7.80E+07	7.80E+07	7.80E+07	7.80E+07	1.10E+08	1.10E+08	1.10E+08	1.10E+08
8*	Crop	2.30E+07	2.30E+07	2.30E+07	2.30E+07	2.30E+07	2.30E+07	2.30E+07	2.30E+07	2.30E+07	2.30E+07	2.30E+07	2.30E+07
8*	Pasture	2.60E+07	2.60E+07	2.60E+07	2.60E+07	2.60E+07	2.60E+07	2.60E+07	2.60E+07	2.60E+07	2.60E+07	2.60E+07	2.60E+07
8*	LDR	5.90E+10	5.90E+10	5.90E+10	5.90E+10	5.90E+10	5.90E+10	5.90E+10	5.90E+10	5.90E+10	5.90E+10	5.90E+10	5.90E+10
8*	Forest	1.00E+08	1.00E+08	7.60E+07	7.60E+07	7.60E+07	7.60E+07	7.60E+07	7.60E+07	1.00E+08	1.00E+08	1.00E+08	1.00E+08

*Sub-watershed is a part of Snow Creek

Table E.5. MON-ACCUM Table for Pigg River – Continued.

Sub-watershed	Land Use	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
9	Crop	4.90E+07	4.90E+07	2.90E+08	2.60E+08	2.40E+08	1.80E+07	1.80E+07	1.80E+07	1.80E+07	2.40E+08	1.80E+08	4.90E+07
9	Pasture	3.30E+09	3.70E+09	4.20E+09	4.30E+09	4.30E+09	4.40E+09	4.40E+09	4.50E+09	4.70E+09	3.30E+09	3.40E+09	3.20E+09
9	LDR	4.30E+09	4.30E+09	4.30E+09	4.30E+09	4.30E+09	4.30E+09	4.30E+09	4.30E+09	4.30E+09	4.30E+09	4.30E+09	4.30E+09
9	HDR	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
9	Forest	9.00E+07	9.00E+07	6.80E+07	6.80E+07	6.80E+07	6.80E+07	6.80E+07	6.80E+07	9.00E+07	9.00E+07	9.00E+07	9.00E+07
10*	Crop	3.40E+07	3.40E+07	1.60E+08	1.50E+08	1.30E+08	1.80E+07	1.80E+07	1.80E+07	1.80E+07	1.30E+08	9.90E+07	3.40E+07
10*	Pasture	3.50E+09	4.00E+09	4.50E+09	4.60E+09	4.70E+09	4.70E+09	4.80E+09	4.90E+09	5.10E+09	3.50E+09	3.60E+09	3.40E+09
10*	LDR	4.20E+09	4.20E+09	4.20E+09	4.20E+09	4.20E+09	4.20E+09	4.20E+09	4.20E+09	4.20E+09	4.20E+09	4.20E+09	4.20E+09
10*	HDR	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
10*	Forest	9.60E+07	9.60E+07	7.20E+07	7.20E+07	7.20E+07	7.20E+07	7.20E+07	7.20E+07	9.60E+07	9.60E+07	9.60E+07	9.60E+07
11*	Crop	1.00E+08	1.10E+08	1.20E+09	1.10E+09	9.80E+08	1.80E+07	1.80E+07	1.80E+07	1.80E+07	1.10E+09	7.40E+08	1.00E+08
11*	Pasture	1.10E+09	1.20E+09	1.50E+09	1.50E+09	1.60E+09	1.60E+09	1.60E+09	1.60E+09	1.60E+09	1.30E+09	1.40E+09	1.10E+09
11*	LDR	9.10E+09	9.10E+09	9.10E+09	9.10E+09	9.10E+09	9.10E+09	9.10E+09	9.10E+09	9.10E+09	9.10E+09	9.10E+09	9.10E+09
11*	HDR	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
11*	Forest	8.80E+07	8.80E+07	6.60E+07	6.60E+07	6.60E+07	6.60E+07	6.60E+07	6.60E+07	8.80E+07	8.80E+07	8.80E+07	8.80E+07
12*	Crop	4.90E+07	4.90E+07	3.10E+08	2.90E+08	2.60E+08	1.80E+07	1.80E+07	1.80E+07	1.80E+07	2.60E+08	1.90E+08	4.90E+07
12*	Pasture	1.70E+09	1.90E+09	2.10E+09	2.20E+09	2.20E+09	2.20E+09	2.20E+09	2.30E+09	2.40E+09	1.70E+09	1.80E+09	1.70E+09
12*	LDR	1.40E+10	1.40E+10	1.40E+10	1.40E+10	1.40E+10	1.40E+10	1.40E+10	1.40E+10	1.40E+10	1.40E+10	1.40E+10	1.40E+10
12*	HDR	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
12*	Forest	1.00E+08	1.00E+08	7.70E+07	7.70E+07	7.70E+07	7.70E+07	7.70E+07	7.70E+07	1.00E+08	1.00E+08	1.00E+08	1.00E+08
13	Crop	1.90E+07	1.90E+07	1.90E+07	1.90E+07	1.90E+07	1.90E+07	1.90E+07	1.90E+07	1.90E+07	1.90E+07	1.90E+07	1.90E+07
13	Pasture	1.90E+07	1.90E+07	1.90E+07	1.90E+07	1.90E+07	1.90E+07	1.90E+07	1.90E+07	1.90E+07	1.90E+07	1.90E+07	1.90E+07
13	LDR	9.10E+10	9.10E+10	9.10E+10	9.10E+10	9.10E+10	9.10E+10	9.10E+10	9.10E+10	9.10E+10	9.10E+10	9.10E+10	9.10E+10
13	Forest	8.40E+07	8.40E+07	6.30E+07	6.30E+07	6.30E+07	6.30E+07	6.30E+07	6.30E+07	8.40E+07	8.40E+07	8.40E+07	8.40E+07
14	Crop	1.90E+07	1.90E+07	1.90E+07	1.90E+07	1.90E+07	1.90E+07	1.90E+07	1.90E+07	1.90E+07	1.90E+07	1.90E+07	1.90E+07
14	Pasture	1.20E+09	1.40E+09	1.40E+09	1.40E+09	1.50E+09	1.50E+09	1.50E+09	1.60E+09	1.60E+09	1.00E+09	1.10E+09	1.10E+09
14	LDR	4.00E+09	4.00E+09	4.00E+09	4.00E+09	4.00E+09	4.00E+09	4.00E+09	4.00E+09	4.00E+09	4.00E+09	4.00E+09	4.00E+09
14	Forest	9.90E+07	9.90E+07	7.40E+07	7.40E+07	7.40E+07	7.40E+07	7.40E+07	7.40E+07	9.90E+07	9.90E+07	9.90E+07	9.90E+07
15	Crop	1.20E+08	1.20E+08	1.70E+09	1.60E+09	1.40E+09	1.90E+07	1.90E+07	1.90E+07	1.90E+07	1.40E+09	9.70E+08	1.20E+08
15	Pasture	3.10E+09	3.20E+09	5.20E+09	5.50E+09	5.50E+09	5.40E+09	5.40E+09	5.50E+09	5.60E+09	5.10E+09	4.90E+09	3.00E+09
15	LDR	2.90E+09	2.90E+09	2.90E+09	2.90E+09	2.90E+09	2.90E+09	2.90E+09	2.90E+09	2.90E+09	2.90E+09	2.90E+09	2.90E+09
15	HDR	1.90E+09	1.90E+09	1.90E+09	1.90E+09	1.90E+09	1.90E+09	1.90E+09	1.90E+09	1.90E+09	1.90E+09	1.90E+09	1.90E+09
15	Forest	1.20E+08	1.20E+08	9.10E+07	9.10E+07	9.10E+07	9.10E+07	9.10E+07	9.10E+07	1.20E+08	1.20E+08	1.20E+08	1.20E+08

*Sub-watershed is a part of Snow Creek

Table E.5. MON-ACCUM Table for Pigg River – Continued.

Sub-watershed	Land Use	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
16	Crop	5.50E+07	5.50E+07	3.10E+08	2.80E+08	2.60E+08	1.80E+07	1.80E+07	1.80E+07	1.80E+07	2.50E+08	1.80E+08	5.50E+07
16	Pasture	1.70E+09	1.90E+09	2.10E+09	2.10E+09	2.20E+09	2.20E+09	2.20E+09	2.20E+09	2.30E+09	1.80E+09	1.80E+09	1.70E+09
16	LDR	2.20E+10	2.20E+10	2.20E+10	2.20E+10	2.20E+10	2.20E+10	2.20E+10	2.20E+10	2.20E+10	2.20E+10	2.20E+10	2.20E+10
16	HDR	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
16	Forest	1.00E+08	1.00E+08	7.50E+07	7.50E+07	7.50E+07	7.50E+07	7.50E+07	7.50E+07	1.00E+08	1.00E+08	1.00E+08	1.00E+08
17	Crop	1.90E+07	1.90E+07	1.90E+07	1.90E+07	1.90E+07	1.90E+07	1.90E+07	1.90E+07	1.90E+07	1.90E+07	1.90E+07	1.90E+07
17	Pasture	5.20E+08	6.10E+08	6.20E+08	6.40E+08	6.60E+08	6.70E+08	6.90E+08	7.10E+08	7.30E+08	4.50E+08	4.80E+08	5.00E+08
17	LDR	9.50E+09	9.50E+09	9.50E+09	9.50E+09	9.50E+09	9.50E+09	9.50E+09	9.50E+09	9.50E+09	9.50E+09	9.50E+09	9.50E+09
17	HDR	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
17	Forest	9.10E+07	9.10E+07	6.90E+07	6.90E+07	6.90E+07	6.90E+07	6.90E+07	6.90E+07	9.10E+07	9.10E+07	9.10E+07	9.10E+07
18	Crop	1.80E+07	1.80E+07	1.80E+07	1.80E+07	1.80E+07	1.80E+07	1.80E+07	1.80E+07	1.80E+07	1.80E+07	1.80E+07	1.80E+07
18	Pasture	6.50E+08	7.60E+08	7.90E+08	8.10E+08	8.30E+08	8.50E+08	8.70E+08	8.90E+08	9.20E+08	5.70E+08	6.00E+08	6.30E+08
18	LDR	1.40E+10	1.40E+10	1.40E+10	1.40E+10	1.40E+10	1.40E+10	1.40E+10	1.40E+10	1.40E+10	1.40E+10	1.40E+10	1.40E+10
18	HDR	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
18	Forest	1.00E+08	1.00E+08	7.70E+07	7.70E+07	7.70E+07	7.70E+07	7.70E+07	7.70E+07	1.00E+08	1.00E+08	1.00E+08	1.00E+08
19	Crop	1.20E+08	1.20E+08	1.70E+09	1.60E+09	1.40E+09	2.10E+07	2.10E+07	2.10E+07	2.10E+07	1.40E+09	9.70E+08	1.20E+08
19	Pasture	3.10E+09	3.30E+09	4.90E+09	5.20E+09	5.20E+09	5.20E+09	5.20E+09	5.30E+09	5.40E+09	4.60E+09	4.40E+09	3.00E+09
19	LDR	2.10E+09	2.10E+09	2.10E+09	2.10E+09	2.10E+09	2.10E+09	2.10E+09	2.10E+09	2.10E+09	2.10E+09	2.10E+09	2.10E+09
19	HDR	1.40E+10	1.40E+10	1.40E+10	1.40E+10	1.40E+10	1.40E+10	1.40E+10	1.40E+10	1.40E+10	1.40E+10	1.40E+10	1.40E+10
19	Forest	9.60E+07	9.60E+07	7.20E+07	7.20E+07	7.20E+07	7.20E+07	7.20E+07	7.20E+07	9.60E+07	9.60E+07	9.60E+07	9.60E+07
20	Crop	1.20E+08	1.20E+08	1.70E+09	1.60E+09	1.40E+09	1.90E+07	1.90E+07	1.90E+07	1.90E+07	1.40E+09	9.70E+08	1.20E+08
20	Pasture	3.00E+09	3.10E+09	5.40E+09	6.30E+09	6.30E+09	6.20E+09	6.20E+09	6.20E+09	6.30E+09	6.10E+09	5.20E+09	3.00E+09
20	LDR	1.60E+10	1.60E+10	1.60E+10	1.60E+10	1.60E+10	1.60E+10	1.60E+10	1.60E+10	1.60E+10	1.60E+10	1.60E+10	1.60E+10
20	HDR	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
20	Forest	1.20E+08	1.20E+08	8.70E+07	8.70E+07	8.70E+07	8.70E+07	8.70E+07	8.70E+07	1.20E+08	1.20E+08	1.20E+08	1.20E+08
21†	Crop	2.10E+08	2.10E+08	1.50E+09	1.30E+09	1.20E+09	1.90E+07	1.90E+07	1.90E+07	1.90E+07	1.20E+09	8.60E+08	2.10E+08
21†	Pasture	4.50E+09	4.90E+09	4.90E+09	5.00E+09	5.00E+09	5.00E+09	5.10E+09	5.10E+09	5.30E+09	4.30E+09	4.40E+09	4.50E+09
21†	LDR	1.90E+10	1.90E+10	1.90E+10	1.90E+10	1.90E+10	1.90E+10	1.90E+10	1.90E+10	1.90E+10	1.90E+10	1.90E+10	1.90E+10
21†	HDR	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
21†	Forest	8.90E+07	8.90E+07	6.70E+07	6.70E+07	6.70E+07	6.70E+07	6.70E+07	6.70E+07	8.90E+07	8.90E+07	8.90E+07	8.90E+07

†Sub-watershed is a part of Story Creek

Table E.5. MON-ACCUM Table for Pigg River – Continued.

Sub-watershed	Land Use	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
22	Crop	1.30E+08	1.30E+08	1.00E+09	9.10E+08	8.30E+08	1.80E+07	1.80E+07	1.80E+07	1.80E+07	8.10E+08	5.80E+08	1.30E+08
22	Pasture	3.20E+09	3.40E+09	4.50E+09	4.60E+09	4.70E+09	4.70E+09	4.70E+09	4.80E+09	4.90E+09	4.20E+09	4.10E+09	3.10E+09
22	LDR	3.00E+10	3.00E+10	3.00E+10	3.00E+10	3.00E+10	3.00E+10	3.00E+10	3.00E+10	3.00E+10	3.00E+10	3.00E+10	3.00E+10
22	HDR	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
22	Forest	7.20E+07	7.20E+07	5.50E+07	5.50E+07	5.50E+07	5.50E+07	5.50E+07	5.50E+07	7.20E+07	7.20E+07	7.20E+07	7.20E+07
23†	Crop	2.00E+07	2.00E+07	2.00E+07	2.00E+07	2.00E+07	2.00E+07	2.00E+07	2.00E+07	2.00E+07	2.00E+07	2.00E+07	2.00E+07
23†	Pasture	1.80E+09	2.10E+09	2.20E+09	2.20E+09	2.30E+09	2.30E+09	2.30E+09	2.40E+09	2.50E+09	1.60E+09	1.60E+09	1.70E+09
23†	LDR	5.00E+09	5.00E+09	5.00E+09	5.00E+09	5.00E+09	5.00E+09	5.00E+09	5.00E+09	5.00E+09	5.00E+09	5.00E+09	5.00E+09
23†	HDR	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
23†	Forest	6.20E+07	6.20E+07	4.90E+07	4.90E+07	4.90E+07	4.90E+07	4.90E+07	4.90E+07	6.20E+07	6.20E+07	6.20E+07	6.20E+07

†Sub-watershed is a part of Story Creek

Table E.6. MON-ACCUM Table for Old Womans Creek

Sub-watershed	Land Use	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	Crop	1.60E+07	1.60E+07	1.60E+07	1.60E+07	1.60E+07	1.60E+07	1.60E+07	1.60E+07	1.60E+07	1.60E+07	1.60E+07	1.60E+07
1	Pasture	1.60E+07	1.60E+07	1.60E+07	1.60E+07	1.60E+07	1.60E+07	1.60E+07	1.60E+07	1.60E+07	1.60E+07	1.60E+07	1.60E+07
1	Forest	8.90E+07	8.90E+07	7.50E+07	7.50E+07	7.50E+07	7.50E+07	7.50E+07	7.50E+07	8.90E+07	8.90E+07	8.90E+07	8.90E+07
2	Crop	1.70E+07	1.70E+07	1.70E+07	1.70E+07	1.70E+07	1.70E+07	1.70E+07	1.70E+07	1.70E+07	1.70E+07	1.70E+07	1.70E+07
2	Pasture	1.70E+07	1.70E+07	1.70E+07	1.70E+07	1.70E+07	1.70E+07	1.70E+07	1.70E+07	1.70E+07	1.70E+07	1.70E+07	1.70E+07
2	LDR	2.30E+10	2.30E+10	2.30E+10	2.30E+10	2.30E+10	2.30E+10	2.30E+10	2.30E+10	2.30E+10	2.30E+10	2.30E+10	2.30E+10
2	Forest	1.30E+08	1.30E+08	9.70E+07	9.70E+07	9.70E+07	9.70E+07	9.70E+07	9.70E+07	1.30E+08	1.30E+08	1.30E+08	1.30E+08
3	Crop	2.00E+07	2.00E+07	2.00E+07	2.00E+07	2.00E+07	2.00E+07	2.00E+07	2.00E+07	2.00E+07	2.00E+07	2.00E+07	2.00E+07
3	Pasture	2.50E+08	2.50E+08	2.50E+08	2.50E+08	2.50E+08	2.50E+08	2.50E+08	2.50E+08	2.50E+08	2.50E+08	2.50E+08	2.50E+08
3	Forest	1.30E+08	1.30E+08	7.60E+07	7.60E+07	7.60E+07	7.60E+07	7.60E+07	7.60E+07	1.30E+08	1.30E+08	1.30E+08	1.30E+08
4	Crop	1.80E+07	5.90E+07	2.00E+08	1.70E+08	5.50E+07	1.80E+07	1.80E+07	1.80E+07	1.80E+07	7.50E+07	7.60E+07	1.80E+07
4	Pasture	7.80E+08	9.20E+08	1.60E+09	1.60E+09	1.60E+09	1.70E+09	1.70E+09	1.80E+09	1.80E+09	1.10E+09	1.20E+09	7.50E+08
4	LDR	9.30E+10	9.30E+10	9.30E+10	9.30E+10	9.30E+10	9.30E+10	9.30E+10	9.30E+10	9.30E+10	9.30E+10	9.30E+10	9.30E+10
4	Forest	8.40E+07	8.40E+07	6.40E+07	6.40E+07	6.40E+07	6.40E+07	6.40E+07	6.40E+07	8.40E+07	8.40E+07	8.40E+07	8.40E+07
5	Crop	1.80E+07	1.20E+08	4.70E+08	3.90E+08	1.10E+08	1.80E+07	1.80E+07	1.80E+07	1.80E+07	1.50E+08	1.60E+08	1.80E+07
5	Pasture	1.70E+09	2.00E+09	3.40E+09	3.50E+09	3.60E+09	3.70E+09	3.80E+09	3.90E+09	4.00E+09	2.40E+09	2.60E+09	1.60E+09
5	LDR	7.40E+09	7.40E+09	7.40E+09	7.40E+09	7.40E+09	7.40E+09	7.40E+09	7.40E+09	7.40E+09	7.40E+09	7.40E+09	7.40E+09
5	Forest	6.70E+07	6.70E+07	5.30E+07	5.30E+07	5.30E+07	5.30E+07	5.30E+07	5.30E+07	6.70E+07	6.70E+07	6.70E+07	6.70E+07
6	Crop	1.80E+07	3.70E+07	1.10E+08	9.10E+07	3.50E+07	1.80E+07	1.80E+07	1.80E+07	1.80E+07	4.50E+07	4.50E+07	1.80E+07
6	Pasture	3.70E+08	4.30E+08	7.20E+08	7.40E+08	7.50E+08	7.70E+08	7.80E+08	8.00E+08	8.30E+08	5.20E+08	5.50E+08	3.50E+08
6	LDR	1.70E+10	1.70E+10	1.70E+10	1.70E+10	1.70E+10	1.70E+10	1.70E+10	1.70E+10	1.70E+10	1.70E+10	1.70E+10	1.70E+10
6	Forest	6.50E+07	6.50E+07	5.10E+07	5.10E+07	5.10E+07	5.10E+07	5.10E+07	5.10E+07	6.50E+07	6.50E+07	6.50E+07	6.50E+07
7	Crop	1.80E+07	2.90E+08	1.30E+09	1.00E+09	2.70E+08	1.80E+07	1.80E+07	1.80E+07	1.80E+07	4.00E+08	4.10E+08	1.80E+07
7	Pasture	8.50E+08	1.00E+09	1.70E+09	1.70E+09	1.80E+09	1.80E+09	1.80E+09	1.90E+09	2.00E+09	1.20E+09	1.30E+09	8.20E+08
7	LDR	1.90E+10	1.90E+10	1.90E+10	1.90E+10	1.90E+10	1.90E+10	1.90E+10	1.90E+10	1.90E+10	1.90E+10	1.90E+10	1.90E+10
7	Forest	8.50E+07	8.50E+07	6.30E+07	6.30E+07	6.30E+07	6.30E+07	6.30E+07	6.30E+07	8.50E+07	8.50E+07	8.50E+07	8.50E+07

Table E.7. MON-SQOLIM Table for Pigg River – Monthly Limit on Surface Accumulation for Bactiera (cfu/ac).

Sub-watershed	Land use	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	Crop	1.70E+08	1.70E+08	1.70E+08	1.70E+08	1.70E+08	1.70E+08	1.70E+08	1.70E+08	1.70E+08	1.70E+08	1.70E+08	1.70E+08
1	Pasture	2.30E+09	2.70E+09	2.80E+09	2.80E+09	2.90E+09	2.90E+09	3.00E+09	3.10E+09	3.20E+09	2.00E+09	2.10E+09	2.20E+09
1	LDR	1.70E+10	1.70E+10	1.70E+10	1.70E+10	1.70E+10	1.70E+10	1.70E+10	1.70E+10	1.70E+10	1.70E+10	1.70E+10	1.70E+10
1	Forest	8.30E+08	8.30E+08	6.20E+08	6.20E+08	6.20E+08	6.20E+08	6.20E+08	6.20E+08	8.30E+08	8.30E+08	8.30E+08	8.30E+08
2	Crop	1.60E+08	1.60E+08	1.60E+08	1.60E+08	1.60E+08	1.60E+08	1.60E+08	1.60E+08	1.60E+08	1.60E+08	1.60E+08	1.60E+08
2	Pasture	1.60E+08	1.60E+08	1.60E+08	1.60E+08	1.60E+08	1.60E+08	1.60E+08	1.60E+08	1.60E+08	1.60E+08	1.60E+08	1.60E+08
2	LDR	6.90E+10	6.90E+10	6.90E+10	6.90E+10	6.90E+10	6.90E+10	6.90E+10	6.90E+10	6.90E+10	6.90E+10	6.90E+10	6.90E+10
2	Forest	6.50E+08	6.50E+08	4.90E+08	4.90E+08	4.90E+08	4.90E+08	4.90E+08	4.90E+08	6.50E+08	6.50E+08	6.50E+08	6.50E+08
3	Crop	1.10E+09	1.20E+09	6.50E+09	5.90E+09	5.40E+09	1.60E+08	1.60E+08	1.60E+08	1.60E+08	5.60E+09	4.30E+09	1.10E+09
3	Pasture	5.60E+10	5.60E+10	7.00E+10	7.00E+10	7.00E+10	7.00E+10	7.00E+10	7.00E+10	7.00E+10	7.00E+10	7.00E+10	5.60E+10
3	LDR	2.90E+10	2.90E+10	2.90E+10	2.90E+10	2.90E+10	2.90E+10	2.90E+10	2.90E+10	2.90E+10	2.90E+10	2.90E+10	2.90E+10
3	Forest	9.20E+08	9.20E+08	6.60E+08	6.60E+08	6.60E+08	6.60E+08	6.60E+08	6.60E+08	9.20E+08	9.20E+08	9.20E+08	9.20E+08
4	Crop	1.60E+08	1.60E+08	1.60E+08	1.60E+08	1.60E+08	1.60E+08	1.60E+08	1.60E+08	1.60E+08	1.60E+08	1.60E+08	1.60E+08
4	Pasture	6.40E+09	7.50E+09	7.70E+09	7.90E+09	8.10E+09	8.30E+09	8.50E+09	8.70E+09	9.00E+09	5.60E+09	5.90E+09	6.20E+09
4	LDR	2.70E+10	2.70E+10	2.70E+10	2.70E+10	2.70E+10	2.70E+10	2.70E+10	2.70E+10	2.70E+10	2.70E+10	2.70E+10	2.70E+10
4	Forest	6.70E+08	6.70E+08	5.10E+08	5.10E+08	5.10E+08	5.10E+08	5.10E+08	5.10E+08	6.70E+08	6.70E+08	6.70E+08	6.70E+08
5	Crop	1.80E+08	1.80E+08	1.80E+08	1.80E+08	1.80E+08	1.80E+08	1.80E+08	1.80E+08	1.80E+08	1.80E+08	1.80E+08	1.80E+08
5	Pasture	1.30E+10	1.60E+10	1.60E+10	1.70E+10	1.70E+10	1.70E+10	1.80E+10	1.80E+10	1.90E+10	1.20E+10	1.20E+10	1.30E+10
5	LDR	2.00E+11	2.00E+11	2.00E+11	2.00E+11	2.00E+11	2.00E+11	2.00E+11	2.00E+11	2.00E+11	2.00E+11	2.00E+11	2.00E+11
5	Forest	6.00E+08	6.00E+08	4.60E+08	4.60E+08	4.60E+08	4.60E+08	4.60E+08	4.60E+08	6.00E+08	6.00E+08	6.00E+08	6.00E+08
6	Crop	1.60E+08	1.60E+08	1.60E+08	1.60E+08	1.60E+08	1.60E+08	1.60E+08	1.60E+08	1.60E+08	1.60E+08	1.60E+08	1.60E+08
6	Pasture	1.60E+08	1.60E+08	1.60E+08	1.60E+08	1.60E+08	1.60E+08	1.60E+08	1.60E+08	1.60E+08	1.60E+08	1.60E+08	1.60E+08
6	LDR	4.00E+10	4.00E+10	4.00E+10	4.00E+10	4.00E+10	4.00E+10	4.00E+10	4.00E+10	4.00E+10	4.00E+10	4.00E+10	4.00E+10
6	Forest	1.10E+09	1.10E+09	8.20E+08	8.20E+08	8.20E+08	8.20E+08	8.20E+08	8.20E+08	1.10E+09	1.10E+09	1.10E+09	1.10E+09
7	Crop	7.80E+08	8.40E+08	2.00E+09	1.80E+09	1.70E+09	1.60E+08	1.60E+08	1.60E+08	1.60E+08	1.40E+09	1.40E+09	7.80E+08
7	Pasture	1.40E+10	1.60E+10	1.60E+10	1.70E+10	1.70E+10	1.70E+10	1.80E+10	1.80E+10	1.90E+10	1.20E+10	1.20E+10	1.30E+10
7	LDR	2.70E+10	2.70E+10	2.70E+10	2.70E+10	2.70E+10	2.70E+10	2.70E+10	2.70E+10	2.70E+10	2.70E+10	2.70E+10	2.70E+10
7	HDR	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01
7	Forest	9.50E+08	9.50E+08	7.00E+08	7.00E+08	7.00E+08	7.00E+08	7.00E+08	7.00E+08	9.50E+08	9.50E+08	9.50E+08	9.50E+08
8*	Crop	2.10E+08	2.10E+08	2.10E+08	2.10E+08	2.10E+08	2.10E+08	2.10E+08	2.10E+08	2.10E+08	2.10E+08	2.10E+08	2.10E+08
8*	Pasture	2.30E+08	2.30E+08	2.30E+08	2.30E+08	2.30E+08	2.30E+08	2.30E+08	2.30E+08	2.30E+08	2.30E+08	2.30E+08	2.30E+08
8*	LDR	5.30E+11	5.30E+11	5.30E+11	5.30E+11	5.30E+11	5.30E+11	5.30E+11	5.30E+11	5.30E+11	5.30E+11	5.30E+11	5.30E+11
8*	Forest	9.10E+08	9.10E+08	6.90E+08	6.90E+08	6.90E+08	6.90E+08	6.90E+08	6.90E+08	9.10E+08	9.10E+08	9.10E+08	9.10E+08

*Sub-watershed is part of Snow Creek

Table E.7. MON-SQOLIM Table for Pigg River – Continued.

Sub-watershed	Land use	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
9	Crop	4.40E+08	4.40E+08	2.60E+09	2.40E+09	2.20E+09	1.60E+08	1.60E+08	1.60E+08	1.60E+08	2.10E+09	1.60E+09	4.40E+08
9	Pasture	2.90E+10	3.40E+10	3.80E+10	3.90E+10	3.90E+10	3.90E+10	4.00E+10	4.10E+10	4.30E+10	3.00E+10	3.10E+10	2.80E+10
9	LDR	3.90E+10	3.90E+10	3.90E+10	3.90E+10	3.90E+10	3.90E+10	3.90E+10	3.90E+10	3.90E+10	3.90E+10	3.90E+10	3.90E+10
9	HDR	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01
9	Forest	8.10E+08	8.10E+08	6.10E+08	6.10E+08	6.10E+08	6.10E+08	6.10E+08	6.10E+08	8.10E+08	8.10E+08	8.10E+08	8.10E+08
10*	Crop	3.10E+08	3.10E+08	1.40E+09	1.30E+09	1.20E+09	1.60E+08	1.60E+08	1.60E+08	1.60E+08	1.20E+09	8.90E+08	3.10E+08
10*	Pasture	3.10E+10	3.60E+10	4.00E+10	4.20E+10	4.20E+10	4.20E+10	4.30E+10	4.40E+10	4.60E+10	3.10E+10	3.20E+10	3.00E+10
10*	LDR	3.80E+10	3.80E+10	3.80E+10	3.80E+10	3.80E+10	3.80E+10	3.80E+10	3.80E+10	3.80E+10	3.80E+10	3.80E+10	3.80E+10
10*	HDR	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01
10*	Forest	8.60E+08	8.60E+08	6.40E+08	6.40E+08	6.40E+08	6.40E+08	6.40E+08	6.40E+08	8.60E+08	8.60E+08	8.60E+08	8.60E+08
11*	Crop	9.00E+08	9.60E+08	1.10E+10	9.70E+09	8.80E+09	1.60E+08	1.60E+08	1.60E+08	1.60E+08	9.70E+09	6.70E+09	9.00E+08
11*	Pasture	9.70E+09	1.10E+10	1.40E+10	1.40E+10	1.40E+10	1.40E+10	1.40E+10	1.40E+10	1.50E+10	1.20E+10	1.20E+10	9.50E+09
11*	LDR	8.20E+10	8.20E+10	8.20E+10	8.20E+10	8.20E+10	8.20E+10	8.20E+10	8.20E+10	8.20E+10	8.20E+10	8.20E+10	8.20E+10
11*	HDR	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01
11*	Forest	8.00E+08	8.00E+08	6.00E+08	6.00E+08	6.00E+08	6.00E+08	6.00E+08	6.00E+08	8.00E+08	8.00E+08	8.00E+08	8.00E+08
12*	Crop	4.40E+08	4.40E+08	2.80E+09	2.60E+09	2.40E+09	1.60E+08	1.60E+08	1.60E+08	1.60E+08	2.30E+09	1.70E+09	4.40E+08
12*	Pasture	1.60E+10	1.80E+10	1.90E+10	2.00E+10	2.00E+10	2.00E+10	2.00E+10	2.10E+10	2.10E+10	1.50E+10	1.60E+10	1.50E+10
12*	LDR	1.30E+11	1.30E+11	1.30E+11	1.30E+11	1.30E+11	1.30E+11	1.30E+11	1.30E+11	1.30E+11	1.30E+11	1.30E+11	1.30E+11
12*	HDR	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01
12*	Forest	9.40E+08	9.40E+08	6.90E+08	6.90E+08	6.90E+08	6.90E+08	6.90E+08	6.90E+08	9.40E+08	9.40E+08	9.40E+08	9.40E+08
13	Crop	1.70E+08	1.70E+08	1.70E+08	1.70E+08	1.70E+08	1.70E+08	1.70E+08	1.70E+08	1.70E+08	1.70E+08	1.70E+08	1.70E+08
13	Pasture	1.70E+08	1.70E+08	1.70E+08	1.70E+08	1.70E+08	1.70E+08	1.70E+08	1.70E+08	1.70E+08	1.70E+08	1.70E+08	1.70E+08
13	LDR	8.20E+11	8.20E+11	8.20E+11	8.20E+11	8.20E+11	8.20E+11	8.20E+11	8.20E+11	8.20E+11	8.20E+11	8.20E+11	8.20E+11
13	Forest	7.60E+08	7.60E+08	5.70E+08	5.70E+08	5.70E+08	5.70E+08	5.70E+08	5.70E+08	7.60E+08	7.60E+08	7.60E+08	7.60E+08
14	Crop	1.70E+08	1.70E+08	1.70E+08	1.70E+08	1.70E+08	1.70E+08	1.70E+08	1.70E+08	1.70E+08	1.70E+08	1.70E+08	1.70E+08
14	Pasture	1.00E+10	1.20E+10	1.30E+10	1.30E+10	1.30E+10	1.40E+10	1.40E+10	1.40E+10	1.50E+10	9.10E+09	9.60E+09	1.00E+10
14	LDR	3.60E+10	3.60E+10	3.60E+10	3.60E+10	3.60E+10	3.60E+10	3.60E+10	3.60E+10	3.60E+10	3.60E+10	3.60E+10	3.60E+10
14	Forest	8.90E+08	8.90E+08	6.70E+08	6.70E+08	6.70E+08	6.70E+08	6.70E+08	6.70E+08	8.90E+08	8.90E+08	8.90E+08	8.90E+08
15	Crop	1.10E+09	1.10E+09	1.50E+10	1.40E+10	1.30E+10	1.70E+08	1.70E+08	1.70E+08	1.70E+08	1.30E+10	8.80E+09	1.10E+09
15	Pasture	2.80E+10	2.90E+10	4.70E+10	4.90E+10	4.90E+10	4.90E+10	4.90E+10	4.90E+10	5.10E+10	4.60E+10	4.40E+10	2.70E+10
15	LDR	2.60E+10	2.60E+10	2.60E+10	2.60E+10	2.60E+10	2.60E+10	2.60E+10	2.60E+10	2.60E+10	2.60E+10	2.60E+10	2.60E+10
15	HDR	1.70E+10	1.70E+10	1.70E+10	1.70E+10	1.70E+10	1.70E+10	1.70E+10	1.70E+10	1.70E+10	1.70E+10	1.70E+10	1.70E+10
15	Forest	1.10E+09	1.10E+09	8.20E+08	8.20E+08	8.20E+08	8.20E+08	8.20E+08	8.20E+08	1.10E+09	1.10E+09	1.10E+09	1.10E+09

*Sub-watershed is part of Snow Creek

Table E.7. MON-SQOLIM Table for Pigg River – Continued.

Sub-watershed	Land use	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
16	Crop	5.00E+08	5.00E+08	2.70E+09	2.50E+09	2.30E+09	1.60E+08	1.60E+08	1.60E+08	1.60E+08	2.20E+09	1.70E+09	5.00E+08
16	Pasture	1.60E+10	1.70E+10	1.90E+10	1.90E+10	2.00E+10	2.00E+10	2.00E+10	2.00E+10	2.10E+10	1.60E+10	1.60E+10	1.50E+10
16	LDR	2.00E+11	2.00E+11	2.00E+11	2.00E+11	2.00E+11	2.00E+11	2.00E+11	2.00E+11	2.00E+11	2.00E+11	2.00E+11	2.00E+11
16	HDR	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01
16	Forest	9.10E+08	9.10E+08	6.80E+08	6.80E+08	6.80E+08	6.80E+08	6.80E+08	6.80E+08	9.10E+08	9.10E+08	9.10E+08	9.10E+08
17	Crop	1.70E+08	1.70E+08	1.70E+08	1.70E+08	1.70E+08	1.70E+08	1.70E+08	1.70E+08	1.70E+08	1.70E+08	1.70E+08	1.70E+08
17	Pasture	4.70E+09	5.50E+09	5.60E+09	5.80E+09	5.90E+09	6.00E+09	6.20E+09	6.40E+09	6.50E+09	4.10E+09	4.30E+09	4.50E+09
17	LDR	8.50E+10	8.50E+10	8.50E+10	8.50E+10	8.50E+10	8.50E+10	8.50E+10	8.50E+10	8.50E+10	8.50E+10	8.50E+10	8.50E+10
17	HDR	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01
17	Forest	8.20E+08	8.20E+08	6.20E+08	6.20E+08	6.20E+08	6.20E+08	6.20E+08	6.20E+08	8.20E+08	8.20E+08	8.20E+08	8.20E+08
18	Crop	1.60E+08	1.60E+08	1.60E+08	1.60E+08	1.60E+08	1.60E+08	1.60E+08	1.60E+08	1.60E+08	1.60E+08	1.60E+08	1.60E+08
18	Pasture	5.90E+09	6.90E+09	7.10E+09	7.30E+09	7.50E+09	7.60E+09	7.80E+09	8.00E+09	8.20E+09	5.10E+09	5.40E+09	5.60E+09
18	LDR	1.30E+11	1.30E+11	1.30E+11	1.30E+11	1.30E+11	1.30E+11	1.30E+11	1.30E+11	1.30E+11	1.30E+11	1.30E+11	1.30E+11
18	HDR	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01
18	Forest	9.40E+08	9.40E+08	7.00E+08	7.00E+08	7.00E+08	7.00E+08	7.00E+08	7.00E+08	9.40E+08	9.40E+08	9.40E+08	9.40E+08
19	Crop	1.10E+09	1.10E+09	1.50E+10	1.40E+10	1.30E+10	1.90E+08	1.90E+08	1.90E+08	1.90E+08	1.30E+10	8.80E+09	1.10E+09
19	Pasture	2.70E+10	3.00E+10	4.40E+10	4.70E+10	4.70E+10	4.60E+10	4.70E+10	4.70E+10	4.90E+10	4.10E+10	4.00E+10	2.70E+10
19	LDR	1.80E+10	1.80E+10	1.80E+10	1.80E+10	1.80E+10	1.80E+10	1.80E+10	1.80E+10	1.80E+10	1.80E+10	1.80E+10	1.80E+10
19	HDR	1.20E+11	1.20E+11	1.20E+11	1.20E+11	1.20E+11	1.20E+11	1.20E+11	1.20E+11	1.20E+11	1.20E+11	1.20E+11	1.20E+11
19	Forest	8.60E+08	8.60E+08	6.50E+08	6.50E+08	6.50E+08	6.50E+08	6.50E+08	6.50E+08	8.60E+08	8.60E+08	8.60E+08	8.60E+08
20	Crop	1.10E+09	1.10E+09	1.50E+10	1.40E+10	1.30E+10	1.70E+08	1.70E+08	1.70E+08	1.70E+08	1.30E+10	8.80E+09	1.10E+09
20	Pasture	2.70E+10	2.80E+10	4.90E+10	5.70E+10	5.60E+10	5.50E+10	5.50E+10	5.60E+10	5.70E+10	5.50E+10	4.70E+10	2.70E+10
20	LDR	1.40E+11	1.40E+11	1.40E+11	1.40E+11	1.40E+11	1.40E+11	1.40E+11	1.40E+11	1.40E+11	1.40E+11	1.40E+11	1.40E+11
20	HDR	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01
20	Forest	1.10E+09	1.10E+09	7.90E+08	7.90E+08	7.90E+08	7.90E+08	7.90E+08	7.90E+08	1.10E+09	1.10E+09	1.10E+09	1.10E+09
21†	Crop	1.90E+09	1.90E+09	1.30E+10	1.20E+10	1.10E+10	1.70E+08	1.70E+08	1.70E+08	1.70E+08	1.10E+10	7.80E+09	1.90E+09
21†	Pasture	4.10E+10	4.40E+10	4.40E+10	4.50E+10	4.50E+10	4.50E+10	4.50E+10	4.60E+10	4.70E+10	3.80E+10	3.90E+10	4.00E+10
21†	LDR	1.70E+11	1.70E+11	1.70E+11	1.70E+11	1.70E+11	1.70E+11	1.70E+11	1.70E+11	1.70E+11	1.70E+11	1.70E+11	1.70E+11
21†	HDR	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01
21†	Forest	8.00E+08	8.00E+08	6.00E+08	6.00E+08	6.00E+08	6.00E+08	6.00E+08	6.00E+08	8.00E+08	8.00E+08	8.00E+08	8.00E+08

†Sub-watershed is part of Story Creek

Table E.7. MON-SQOLIM Table for Pigg River - Continued

Sub-watershed	Land use	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
22	Crop	1.20E+09	1.20E+09	9.00E+09	8.20E+09	7.40E+09	1.60E+08	1.60E+08	1.60E+08	1.60E+08	7.20E+09	5.30E+09	1.20E+09
22	Pasture	2.90E+10	3.10E+10	4.00E+10	4.20E+10	4.20E+10	4.20E+10	4.30E+10	4.30E+10	4.40E+10	3.80E+10	3.70E+10	2.80E+10
22	LDR	2.70E+11	2.70E+11	2.70E+11	2.70E+11	2.70E+11	2.70E+11	2.70E+11	2.70E+11	2.70E+11	2.70E+11	2.70E+11	2.70E+11
22	HDR	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01
22	Forest	6.50E+08	6.50E+08	5.00E+08	5.00E+08	5.00E+08	5.00E+08	5.00E+08	5.00E+08	6.50E+08	6.50E+08	6.50E+08	6.50E+08
23†	Crop	1.80E+08	1.80E+08	1.80E+08	1.80E+08	1.80E+08	1.80E+08	1.80E+08	1.80E+08	1.80E+08	1.80E+08	1.80E+08	1.80E+08
23†	Pasture	1.60E+10	1.90E+10	2.00E+10	2.00E+10	2.10E+10	2.10E+10	2.10E+10	2.20E+10	2.30E+10	1.40E+10	1.50E+10	1.60E+10
23†	LDR	4.50E+10	4.50E+10	4.50E+10	4.50E+10	4.50E+10	4.50E+10	4.50E+10	4.50E+10	4.50E+10	4.50E+10	4.50E+10	4.50E+10
23†	HDR	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01
23†	Forest	5.60E+08	5.60E+08	4.40E+08	4.40E+08	4.40E+08	4.40E+08	4.40E+08	4.40E+08	5.60E+08	5.60E+08	5.60E+08	5.60E+08

†Sub-watershed is a part of Story Creek

Table E.8. MON-SQOLIM Table for Old Womans Creek.

Sub-watershed	Land Use	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	Crop	1.50E+08	1.50E+08	1.50E+08	1.50E+08	1.50E+08	1.50E+08	1.50E+08	1.50E+08	1.50E+08	1.50E+08	1.50E+08	1.50E+08
1	Pasture	1.50E+08	1.50E+08	1.50E+08	1.50E+08	1.50E+08	1.50E+08	1.50E+08	1.50E+08	1.50E+08	1.50E+08	1.50E+08	1.50E+08
1	Forest	8.00E+08	8.00E+08	6.70E+08	6.70E+08	6.70E+08	6.70E+08	6.70E+08	6.70E+08	8.00E+08	8.00E+08	8.00E+08	8.00E+08
2	Crop	1.60E+08	1.60E+08	1.60E+08	1.60E+08	1.60E+08	1.60E+08	1.60E+08	1.60E+08	1.60E+08	1.60E+08	1.60E+08	1.60E+08
2	Pasture	1.60E+08	1.60E+08	1.60E+08	1.60E+08	1.60E+08	1.60E+08	1.60E+08	1.60E+08	1.60E+08	1.60E+08	1.60E+08	1.60E+08
2	LDR	2.00E+11	2.00E+11	2.00E+11	2.00E+11	2.00E+11	2.00E+11	2.00E+11	2.00E+11	2.00E+11	2.00E+11	2.00E+11	2.00E+11
2	Forest	1.10E+09	1.10E+09	8.80E+08	8.80E+08	8.80E+08	8.80E+08	8.80E+08	8.80E+08	1.10E+09	1.10E+09	1.10E+09	1.10E+09
3	Crop	1.80E+08	1.80E+08	1.80E+08	1.80E+08	1.80E+08	1.80E+08	1.80E+08	1.80E+08	1.80E+08	1.80E+08	1.80E+08	1.80E+08
3	Pasture	2.30E+09	2.30E+09	2.30E+09	2.30E+09	2.30E+09	2.30E+09	2.30E+09	2.30E+09	2.30E+09	2.30E+09	2.30E+09	2.30E+09
3	Forest	1.20E+09	1.20E+09	6.80E+08	6.80E+08	6.80E+08	6.80E+08	6.80E+08	6.80E+08	1.20E+09	1.20E+09	1.20E+09	1.20E+09
4	Crop	1.60E+08	5.30E+08	1.80E+09	1.50E+09	5.00E+08	1.60E+08	1.60E+08	1.60E+08	1.60E+08	6.70E+08	6.90E+08	1.60E+08
4	Pasture	7.10E+09	8.20E+09	1.40E+10	1.40E+10	1.50E+10	1.50E+10	1.50E+10	1.60E+10	1.60E+10	1.00E+10	1.10E+10	6.80E+09
4	LDR	8.40E+11	8.40E+11	8.40E+11	8.40E+11	8.40E+11	8.40E+11	8.40E+11	8.40E+11	8.40E+11	8.40E+11	8.40E+11	8.40E+11
4	Forest	7.60E+08	7.60E+08	5.80E+08	5.80E+08	5.80E+08	5.80E+08	5.80E+08	5.80E+08	7.60E+08	7.60E+08	7.60E+08	7.60E+08
5	Crop	1.60E+08	1.00E+09	4.20E+09	3.50E+09	9.60E+08	1.60E+08	1.60E+08	1.60E+08	1.60E+08	1.40E+09	1.40E+09	1.60E+08
5	Pasture	1.50E+10	1.80E+10	3.00E+10	3.10E+10	3.20E+10	3.30E+10	3.40E+10	3.50E+10	3.60E+10	2.20E+10	2.30E+10	1.50E+10
5	LDR	6.60E+10	6.60E+10	6.60E+10	6.60E+10	6.60E+10	6.60E+10	6.60E+10	6.60E+10	6.60E+10	6.60E+10	6.60E+10	6.60E+10
5	Forest	6.10E+08	6.10E+08	4.70E+08	4.70E+08	4.70E+08	4.70E+08	4.70E+08	4.70E+08	6.10E+08	6.10E+08	6.10E+08	6.10E+08
6	Crop	1.60E+08	3.30E+08	9.50E+08	8.20E+08	3.20E+08	1.60E+08	1.60E+08	1.60E+08	1.60E+08	4.00E+08	4.10E+08	1.60E+08
6	Pasture	3.30E+09	3.90E+09	6.50E+09	6.60E+09	6.80E+09	6.90E+09	7.10E+09	7.20E+09	7.50E+09	4.70E+09	4.90E+09	3.20E+09
6	LDR	1.50E+11	1.50E+11	1.50E+11	1.50E+11	1.50E+11	1.50E+11	1.50E+11	1.50E+11	1.50E+11	1.50E+11	1.50E+11	1.50E+11
6	Forest	5.80E+08	5.80E+08	4.60E+08	4.60E+08	4.60E+08	4.60E+08	4.60E+08	4.60E+08	5.80E+08	5.80E+08	5.80E+08	5.80E+08
7	Crop	1.60E+08	2.60E+09	1.10E+10	9.40E+09	2.40E+09	1.60E+08	1.60E+08	1.60E+08	1.60E+08	3.60E+09	3.70E+09	1.60E+08
7	Pasture	7.70E+09	9.00E+09	1.50E+10	1.60E+10	1.60E+10	1.60E+10	1.60E+10	1.70E+10	1.80E+10	1.10E+10	1.20E+10	7.40E+09
7	LDR	1.70E+11	1.70E+11	1.70E+11	1.70E+11	1.70E+11	1.70E+11	1.70E+11	1.70E+11	1.70E+11	1.70E+11	1.70E+11	1.70E+11
7	Forest	7.60E+08	7.60E+08	5.60E+08	5.60E+08	5.60E+08	5.60E+08	5.60E+08	5.60E+08	7.60E+08	7.60E+08	7.60E+08	7.60E+08

Appendix F: Fecal Coliform Loading in Sub-watersheds for Future Conditions

Table F-1. Monthly nonpoint fecal coliform loadings in sub-watershed PGG-1.

Month	Fecal Coliform loadings (x10^{10} cfu/month)			
	Cropland	Pasture	Forest	Residential[1]
Jan.	97	3,738	5,748	2,432
Feb.	92	3,946	5,238	2,216
Mar.	353	4,438	4,307	2,432
Apr.	316	4,399	4,168	2,353
May.	301	4,641	4,307	2,432
Jun.	56	4,518	4,168	2,353
Jul.	58	4,784	4,307	2,432
Aug.	58	4,899	4,307	2,432
Sep.	56	4,946	5,562	2,353
Oct.	313	3,279	5,748	2,432
Nov.	241	3,323	5,562	2,353
Dec.	97	3,590	5,748	2,432
Total	2,039	50,498	59,167	28,652

[1]Includes Farmstead, Low Density Residential, and High Density Residential Loads

Table F-2. Monthly nonpoint fecal coliform loadings in sub-watershed PGG-2.

Month	Fecal Coliform loadings (x10^{10} cfu/month)			
	Cropland	Pasture	Forest	Residential[1]
Jan.	1	10	322	89
Feb.	1	9	293	81
Mar.	1	10	244	89
Apr.	1	10	236	86
May.	1	10	244	89
Jun.	1	10	236	86
Jul.	1	10	244	89
Aug.	1	10	244	89
Sep.	1	10	312	86
Oct.	1	10	322	89
Nov.	1	10	312	86
Dec.	1	10	322	89
Total	17	121	3,329	1,047

[1]Includes Farmstead, Low Density Residential, and High Density Residential Loads

Table F-3. Monthly nonpoint fecal coliform loadings in sub-watershed PGG-3.

Month	Fecal Coliform loadings ($x10^{10}$ cfu/month)			
	Cropland	Pasture	Forest	Residential[1]
Jan.	14	88,361	133	68
Feb.	13	80,525	121	62
Mar.	212	100,803	96	68
Apr.	188	97,505	93	66
May.	177	100,704	96	68
Jun.	2	97,143	93	66
Jul.	2	100,277	96	68
Aug.	2	100,277	96	68
Sep.	2	97,340	129	66
Oct.	200	100,770	133	68
Nov.	130	97,340	129	66
Dec.	14	88,361	133	68
Total	955	1,149,408	1,348	802

[1]Includes Farmstead, Low Density Residential, and High Density Residential Loads

Table F-4. Monthly nonpoint fecal coliform loadings in sub-watershed PGG-4.

Month	Fecal Coliform loadings ($x10^{10}$ cfu/month)			
	Cropland	Pasture	Forest	Residential[1]
Jan.	31	2,634	1,373	568
Feb.	29	2,806	1,251	518
Mar.	114	3,166	1,052	568
Apr.	102	3,147	1,018	550
May.	97	3,335	1,052	568
Jun.	17	3,288	1,018	550
Jul.	18	3,486	1,052	568
Aug.	18	3,574	1,052	568
Sep.	17	3,571	1,329	550
Oct.	101	2,296	1,373	568
Nov.	77	2,331	1,329	550
Dec.	31	2,523	1,373	568
Total	651	36,156	14,270	6,695

[1]Includes Farmstead, Low Density Residential, and High Density Residential Loads

Table F-5. Monthly nonpoint fecal coliform loadings in sub-watershed PGG-5.

Month	Fecal Coliform loadings ($x10^{10}$ cfu/month)			
	Cropland	Pasture	Forest	Residential[1]
Jan.	2	695	126	39
Feb.	2	742	115	36
Mar.	7	838	98	39
Apr.	7	834	95	38
May.	6	886	98	39
Jun.	1	880	95	38
Jul.	1	933	98	39
Aug.	1	957	98	39
Sep.	1	949	122	38
Oct.	6	606	126	39
Nov.	5	615	122	38
Dec.	2	665	126	39
Total	42	9,601	1,320	464

[1]Includes Farmstead, Low Density Residential, and High Density Residential Loads

Table F-6. Monthly nonpoint fecal coliform loadings in sub-watershed PGG-6.

Month	Fecal Coliform loadings ($x10^{10}$ cfu/month)			
	Cropland	Pasture	Forest	Residential[1]
Jan.	19	115	945	461
Feb.	17	104	861	420
Mar.	19	115	686	461
Apr.	18	111	664	446
May.	19	115	686	461
Jun.	18	111	664	446
Jul.	19	115	686	461
Aug.	19	115	686	461
Sep.	18	111	914	446
Oct.	19	115	945	461
Nov.	18	111	914	446
Dec.	19	115	945	461
Total	221	1,351	9,597	5,428

[1]Includes Farmstead, Low Density Residential, and High Density Residential Loads

Table F-7. Monthly nonpoint fecal coliform loadings in sub-watershed PGG-7.

Month	Fecal Coliform loadings ($x10^{10}$ cfu/month)			
	Cropland	Pasture	Forest	Residential[1]
Jan.	156	15,020	2,304	1,051
Feb.	154	16,037	2,099	958
Mar.	504	18,078	1,706	1,051
Apr.	442	17,957	1,651	1,017
May.	412	18,993	1,706	1,051
Jun.	27	18,571	1,651	1,017
Jul.	27	19,693	1,706	1,051
Aug.	27	20,196	1,706	1,051
Sep.	27	20,360	2,229	1,017
Oct.	375	13,034	2,304	1,051
Nov.	338	13,261	2,229	1,017
Dec.	156	14,375	2,304	1,051
Total	2,645	205,576	23,594	12,380

[1]Includes Farmstead, Low Density Residential, and High Density Residential Loads

Table F-8. Monthly nonpoint fecal coliform loadings in sub-watershed PGG-8.[†]

Month	Fecal Coliform loadings ($x10^{10}$ cfu/month)			
	Cropland	Pasture	Forest	Residential[1]
Jan.	3	15	123	41
Feb.	3	13	113	37
Mar.	11	15	93	41
Apr.	10	14	90	39
May.	10	15	93	41
Jun.	2	14	90	39
Jul.	2	15	93	41
Aug.	2	15	93	41
Sep.	2	14	120	39
Oct.	10	15	123	41
Nov.	8	14	120	39
Dec.	3	15	123	41
Total	68	172	1,276	479

[†]Sub-watershed is a part of Snow Creek
[1]Includes Farmstead, Low Density Residential, and High Density Residential Loads

Table F-9. Monthly nonpoint fecal coliform loadings in sub-watershed PGG-9.

Month	Fecal Coliform loadings ($x10^{10}$ cfu/month)			
	Cropland	Pasture	Forest	Residential[1]
Jan.	104	43,227	4,936	2,453
Feb.	95	45,335	4,498	2,235
Mar.	549	52,576	3,713	2,453
Apr.	488	52,049	3,593	2,373
May.	460	54,386	3,713	2,453
Jun.	38	53,119	3,593	2,373
Jul.	40	56,162	3,713	2,453
Aug.	40	57,435	3,713	2,453
Sep.	38	58,128	4,777	2,373
Oct.	451	39,820	4,936	2,453
Nov.	328	40,174	4,777	2,373
Dec.	104	41,597	4,936	2,453
Total	2,735	594,010	50,898	28,897

[1]Includes Farmstead, Low Density Residential, and High Density Residential Loads

Table F-10. Monthly nonpoint fecal coliform loadings in sub-watershed PGG-10.[†]

Month	Fecal Coliform loadings ($x10^{10}$ cfu/month)			
	Cropland	Pasture	Forest	Residential[1]
Jan.	58	30,465	2,439	1,452
Feb.	53	32,559	2,222	1,324
Mar.	199	36,667	1,825	1,452
Apr.	179	36,385	1,766	1,406
May.	170	38,401	1,825	1,452
Jun.	33	37,200	1,766	1,406
Jul.	34	39,453	1,825	1,452
Aug.	34	40,467	1,825	1,452
Sep.	33	41,186	2,360	1,406
Oct.	164	26,351	2,439	1,452
Nov.	127	26,851	2,360	1,406
Dec.	58	29,149	2,439	1,452
Total	1,141	415,133	25,088	17,113

[†]Sub-watershed is part of Snow Creek
[1]Includes Farmstead, Low Density Residential, and High Density Residential Loads

Table F-11. Monthly nonpoint fecal coliform loadings in sub-watershed PGG-11.†

Month	Fecal Coliform loadings ($x10^{10}$ cfu/month)			
	Cropland	Pasture	Forest	Residential[1]
Jan.	306	14,847	5,190	2,406
Feb.	298	14,770	4,730	2,192
Mar.	3,527	20,948	3,898	2,406
Apr.	3,135	20,505	3,772	2,328
May.	2,941	21,396	3,898	2,406
Jun.	51	20,716	3,772	2,328
Jul.	53	21,668	3,898	2,406
Aug.	53	21,930	3,898	2,406
Sep.	51	21,746	5,023	2,328
Oct.	3,245	18,282	5,190	2,406
Nov.	2,164	18,041	5,023	2,328
Dec.	306	14,507	5,190	2,406
Total	16,130	229,359	53,480	28,346

†Sub-watershed is part of Snow Creek
[1]Includes Farmstead, Low Density Residential, and High Density Residential Loads

Table F-12. Monthly nonpoint fecal coliform loadings in sub-watershed PGG-12.†

Month	Fecal Coliform loadings ($x10^{10}$ cfu/month)			
	Cropland	Pasture	Forest	Residential[1]
Jan.	188	45,039	6,252	3,349
Feb.	171	46,218	5,698	3,052
Mar.	1,220	55,462	4,627	3,349
Apr.	1,084	54,645	4,478	3,241
May.	1,019	57,332	4,627	3,349
Jun.	54	55,524	4,478	3,241
Jul.	56	58,468	4,627	3,349
Aug.	56	59,561	4,627	3,349
Sep.	54	59,824	6,051	3,241
Oct.	997	44,335	6,252	3,349
Nov.	705	44,361	6,051	3,241
Dec.	188	43,620	6,252	3,349
Total	5,792	624,390	64,020	39,463

†Sub-watershed is part of Snow Creek
[1]Includes Farmstead, Low Density Residential, and High Density Residential Loads

Table F-13. Monthly nonpoint fecal coliform loadings in sub-watershed PGG-13.

Month	Fecal Coliform loadings ($x10^{10}$ cfu/month)			
	Cropland	Pasture	Forest	Residential[1]
Jan.	4	35	378	442
Feb.	4	31	345	403
Mar.	4	35	285	442
Apr.	4	33	276	428
May.	4	35	285	442
Jun.	4	33	276	428
Jul.	4	35	285	442
Aug.	4	35	285	442
Sep.	4	33	366	428
Oct.	4	35	378	442
Nov.	4	33	366	428
Dec.	4	35	378	442
Total	47	407	3,901	5,207

[1]Includes Farmstead, Low Density Residential, and High Density Residential Loads

Table F-14. Monthly nonpoint fecal coliform loadings in sub-watershed PGG-14.

Month	Fecal Coliform loadings ($x10^{10}$ cfu/month)			
	Cropland	Pasture	Forest	Residential[1]
Jan.	14	4,178	2,171	1,239
Feb.	13	4,457	1,978	1,129
Mar.	47	5,031	1,622	1,239
Apr.	43	5,003	1,570	1,199
May.	41	5,306	1,622	1,239
Jun.	8	5,246	1,570	1,199
Jul.	8	5,563	1,622	1,239
Aug.	8	5,704	1,622	1,239
Sep.	8	5,686	2,101	1,199
Oct.	39	3,638	2,171	1,239
Nov.	30	3,695	2,101	1,199
Dec.	14	3,999	2,171	1,239
Total	275	57,507	22,319	14,603

[1]Includes Farmstead, Low Density Residential, and High Density Residential Loads

Table F-15. Monthly nonpoint fecal coliform loadings in sub-watershed PGG-15.

Month	Fecal Coliform loadings ($x10^{10}$ cfu/month)			
	Cropland	Pasture	Forest	Residential[1]
Jan.	144	30,086	2,787	5,077
Feb.	131	29,370	2,540	4,627
Mar.	1,988	48,193	2,050	5,077
Apr.	1,769	48,909	1,984	4,914
May.	1,661	50,748	2,050	5,077
Jun.	23	48,645	1,984	4,914
Jul.	24	50,668	2,050	5,077
Aug.	24	51,086	2,050	5,077
Sep.	23	50,711	2,698	4,914
Oct.	1,696	45,910	2,787	5,077
Nov.	1,105	43,030	2,698	4,914
Dec.	144	29,552	2,787	5,077
Total	8,732	526,908	28,463	59,822

[1]Includes Farmstead, Low Density Residential, and High Density Residential Loads

Table F-16. Monthly nonpoint fecal coliform loadings in sub-watershed PGG-16.

Month	Fecal Coliform loadings ($x10^{10}$ cfu/month)			
	Cropland	Pasture	Forest	Residential[1]
Jan.	30	11,124	1,580	3,053
Feb.	28	11,864	1,440	2,782
Mar.	101	13,367	1,171	3,053
Apr.	91	13,271	1,133	2,954
May.	87	14,026	1,171	3,053
Jun.	18	13,676	1,133	2,954
Jul.	18	14,500	1,171	3,053
Aug.	18	14,868	1,171	3,053
Sep.	18	15,027	1,529	2,954
Oct.	83	9,657	1,580	3,053
Nov.	65	9,825	1,529	2,954
Dec.	30	10,650	1,580	3,053
Total	587	151,855	16,192	35,969

[1]Includes Farmstead, Low Density Residential, and High Density Residential Loads

Table F-17. Monthly nonpoint fecal coliform loadings in sub-watershed PGG-17.

Month	Fecal Coliform loadings (x10^{10} cfu/month)			
	Cropland	**Pasture**	**Forest**	**Residential**[1]
Jan.	20	4,271	2,339	2,377
Feb.	18	4,543	2,132	2,166
Mar.	65	5,129	1,760	2,377
Apr.	58	5,101	1,704	2,301
May.	56	5,414	1,760	2,377
Jun.	12	5,378	1,704	2,301
Jul.	12	5,700	1,760	2,377
Aug.	12	5,843	1,760	2,377
Sep.	12	5,793	2,264	2,301
Oct.	53	3,736	2,339	2,377
Nov.	42	3,788	2,264	2,301
Dec.	20	4,093	2,339	2,377
Total	379	58,789	24,126	28,011

[1]Includes Farmstead, Low Density Residential, and High Density Residential Loads

Table F-18. Monthly nonpoint fecal coliform loadings in sub-watershed PGG-18.

Month	Fecal Coliform loadings (x10^{10} cfu/month)			
	Cropland	**Pasture**	**Forest**	**Residential**[1]
Jan.	31	8,462	4,800	3,447
Feb.	28	9,012	4,374	3,142
Mar.	108	10,168	3,554	3,447
Apr.	96	10,110	3,439	3,336
May.	92	10,719	3,554	3,447
Jun.	17	10,596	3,439	3,336
Jul.	18	11,233	3,554	3,447
Aug.	18	11,516	3,554	3,447
Sep.	17	11,475	4,645	3,336
Oct.	88	7,383	4,800	3,447
Nov.	68	7,494	4,645	3,336
Dec.	31	8,106	4,800	3,447
Total	614	116,274	49,155	40,618

[1]Includes Farmstead, Low Density Residential, and High Density Residential Loads

Table F-19. Monthly nonpoint fecal coliform loadings in sub-watershed PGG-19.

	Fecal Coliform loadings ($x10^{10}$ cfu/month)			
Month	Cropland	Pasture	Forest	Residential[1]
Jan.	3	13,755	1,653	5,791
Feb.	3	13,618	1,506	5,277
Mar.	32	22,217	1,262	5,791
Apr.	29	22,783	1,221	5,604
May.	27	23,652	1,262	5,791
Jun.	1	22,549	1,221	5,604
Jul.	1	23,470	1,262	5,791
Aug.	1	23,700	1,262	5,791
Sep.	1	23,722	1,599	5,604
Oct.	28	21,000	1,653	5,791
Nov.	18	19,412	1,599	5,604
Dec.	3	13,459	1,653	5,791
Total	148	243,337	17,155	68,231

[1]Includes Farmstead, Low Density Residential, and High Density Residential Loads

Table F-20. Monthly nonpoint fecal coliform loadings in sub-watershed PGG-20.

	Fecal Coliform loadings ($x10^{10}$ cfu/month)			
Month	Cropland	Pasture	Forest	Residential[1]
Jan.	30	14,472	1,138	3,275
Feb.	28	13,625	1,037	2,984
Mar.	392	26,363	841	3,275
Apr.	349	29,450	813	3,169
May.	327	30,354	841	3,275
Jun.	7	28,716	813	3,169
Jul.	7	29,700	841	3,275
Aug.	7	29,791	841	3,275
Sep.	7	29,651	1,101	3,169
Oct.	334	29,397	1,138	3,275
Nov.	218	24,566	1,101	3,169
Dec.	30	14,353	1,138	3,275
Total	1,736	300,439	11,644	38,581

[1]Includes Farmstead, Low Density Residential, and High Density Residential Loads

Table F-21. Monthly nonpoint fecal coliform loadings in sub-watershed PGG-21.†

Month	Fecal Coliform loadings ($x10^{10}$ cfu/month)			
	Cropland	Pasture	Forest	Residential[1]
Jan.	16	20,607	2,159	3,609
Feb.	14	20,511	1,967	3,289
Mar.	196	23,068	1,647	3,609
Apr.	175	22,619	1,594	3,493
May.	164	23,627	1,647	3,609
Jun.	4	22,702	1,594	3,493
Jul.	4	23,795	1,647	3,609
Aug.	4	24,163	1,647	3,609
Sep.	4	24,273	2,089	3,493
Oct.	168	19,297	2,159	3,609
Nov.	110	19,119	2,089	3,493
Dec.	16	20,133	2,159	3,609
Total	873	263,914	22,397	42,524

†Sub-watershed is a part of Story Creek
[1]Includes Farmstead, Low Density Residential, and High Density Residential Loads

Table F-22. Monthly nonpoint fecal coliform loadings in sub-watershed PGG-22.

Month	Fecal Coliform loadings ($x10^{10}$ cfu/month)			
	Cropland	Pasture	Forest	Residential[1]
Jan.	134	25,634	4,050	2,393
Feb.	122	25,292	3,691	2,181
Mar.	950	32,780	3,111	2,393
Apr.	842	32,304	3,011	2,316
May.	789	33,744	3,111	2,393
Jun.	23	32,830	3,011	2,316
Jul.	24	34,338	3,111	2,393
Aug.	24	34,753	3,111	2,393
Sep.	23	34,284	3,920	2,316
Oct.	767	28,840	4,050	2,393
Nov.	542	28,242	3,920	2,316
Dec.	134	25,104	4,050	2,393
Total	4,372	368,143	42,146	28,197

[1]Includes Farmstead, Low Density Residential, and High Density Residential Loads

Table F-23. Monthly nonpoint fecal coliform loadings in sub-watershed PGG-23.†

Month	Fecal Coliform loadings ($x10^{10}$ cfu/month)			
	Cropland	Pasture	Forest	Residential[1]
Jan.	1	1,374	217	1,377
Feb.	1	1,468	198	1,255
Mar.	2	1,653	170	1,377
Apr.	2	1,640	165	1,333
May.	2	1,731	170	1,377
Jun.	1	1,677	165	1,333
Jul.	1	1,778	170	1,377
Aug.	1	1,824	170	1,377
Sep.	1	1,856	210	1,333
Oct.	2	1,190	217	1,377
Nov.	2	1,212	210	1,333
Dec.	1	1,315	217	1,377
Total	15	18,720	2,280	16,229

†Sub-watershed is a part of Story Creek
[1]Includes Farmstead, Low Density Residential, and High Density Residential Loads

Table F-24. Monthly nonpoint fecal coliform loadings in sub-watershed OWC-1.

Month	Fecal Coliform loadings (x10^{10} cfu/month)			
	Cropland	Pasture	Forest	Low Density Residential
Jan.	0	1	15	18
Feb.	0	1	13	17
Mar.	0	1	12	18
Apr.	0	1	12	18
May.	0	1	12	18
Jun.	0	1	12	18
Jul.	0	1	12	18
Aug.	0	1	12	18
Sep.	0	1	14	18
Oct.	0	1	15	18
Nov.	0	1	14	18
Dec.	0	1	15	18
Total	0	10	158	216

Table F-25. Monthly nonpoint fecal coliform loadings in sub-watershed OWC-2.

Month	Fecal Coliform loadings (x10^{10} cfu/month)			
	Cropland	Pasture	Forest	Low Density Residential
Jan.	1	4	94	99
Feb.	1	3	85	90
Mar.	1	4	73	99
Apr.	1	4	70	95
May.	1	4	73	99
Jun.	1	4	70	95
Jul.	1	4	73	99
Aug.	1	4	73	99
Sep.	1	4	91	95
Oct.	1	4	94	99
Nov.	1	4	91	95
Dec.	1	4	94	99
Total	9	44	978	1,161

Table F-26. Monthly nonpoint fecal coliform loadings in sub-watershed OWC-3.

Month	Fecal Coliform loadings (x10^{10} cfu/month)			
	Cropland	Pasture	Forest	Low Density Residential
Jan.	0	7	22	1
Feb.	0	6	20	1
Mar.	0	7	13	1
Apr.	0	7	12	1
May.	0	7	13	1
Jun.	0	7	12	1
Jul.	0	7	13	1
Aug.	0	7	13	1
Sep.	0	7	21	1
Oct.	0	7	22	1
Nov.	0	7	21	1
Dec.	0	7	22	1
Total	1	83	204	16

Table F-27. Monthly nonpoint fecal coliform loadings in sub-watershed OWC-4.

Month	Fecal Coliform loadings (x10^{10} cfu/month)			
	Cropland	Pasture	Forest	Low Density Residential
Jan.	6	1,625	431	270
Feb.	17	1,731	393	246
Mar.	64	3,222	329	270
Apr.	52	3,202	318	262
May.	17	3,393	329	270
Jun.	5	3,341	318	262
Jul.	6	3,543	329	270
Aug.	6	3,633	329	270
Sep.	5	3,636	417	262
Oct.	23	2,328	431	270
Nov.	23	2,366	417	262
Dec.	6	1,556	431	270
Total	229	33,575	4,473	3,184

Table F-28. Monthly nonpoint fecal coliform loadings in sub-watershed OWC-5.

Month	Fecal Coliform loadings ($x10^{10}$ cfu/month)			
	Cropland	Pasture	Forest	Low Density Residential
Jan.	4	2,886	342	277
Feb.	25	3,082	312	253
Mar.	109	5,780	268	277
Apr.	88	5,753	259	268
May.	25	6,108	268	277
Jun.	4	6,063	259	268
Jul.	4	6,430	268	277
Aug.	4	6,595	268	277
Sep.	4	6,551	331	268
Oct.	36	4,167	342	277
Nov.	36	4,233	331	268
Dec.	4	2,762	342	277
Total	344	60,410	3,591	3,269

Table F-29. Monthly nonpoint fecal coliform loadings in sub-watershed OWC-6.

Month	Fecal Coliform loadings ($x10^{10}$ cfu/month)			
	Cropland	Pasture	Forest	Low Density Residential
Jan.	2	328	306	73
Feb.	4	348	278	67
Mar.	14	639	240	73
Apr.	11	634	233	71
May.	5	671	240	73
Jun.	2	658	233	71
Jul.	2	698	240	73
Aug.	2	715	240	73
Sep.	2	718	296	71
Oct.	6	465	306	73
Nov.	6	472	296	71
Dec.	2	315	306	73
Total	59	6,660	3,214	862

Table F-30. Monthly nonpoint fecal coliform loadings in sub-watershed OWC-7.

Month	Fecal Coliform loadings ($x10^{10}$ cfu/month)			
	Cropland	Pasture	Forest	Low Density Residential
Jan.	0	354	288	45
Feb.	3	378	262	41
Mar.	13	704	213	45
Apr.	10	699	206	44
May.	3	737	213	45
Jun.	0	714	206	44
Jul.	0	757	213	45
Aug.	0	777	213	45
Sep.	0	790	278	44
Oct.	4	507	288	45
Nov.	4	517	278	44
Dec.	0	339	288	45
Total	38	7,274	2,949	531

Appendix G: Required Reductions in Fecal Coliform Loads by Sub-watershed – Allocation Scenario

Table G-1a. Required annual reductions in nonpoint sources in sub-watershed PGG-1.

Land Use	Current conditions load (x 10^8 cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cropland	203,863	1%	203,863	0%
Pasture	5,049,818	36%	252,491	95%
Forest	5,916,724	42%	5,916,724	0%
Residential	2,865,167	20%	286,517	90%
Total	14,035,571	100%	6,659,594	53%

Table G-1b. Required annual reductions in direct nonpoint sources in sub-watershed PGG-1.

Source	Current Conditions load (x 10^8 cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cattle in Streams	79,174	11%	0	100%
Wildlife in Streams	657,182	89%	460,027	30%
Straight Pipes	0	0%	0	100%
Total	736,356	100%	460,027	38%

Table G-2a. Required annual reductions in nonpoint sources in sub-watershed PGG-2.

Land Use	Current conditions load (x 10^8 cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cropland	1,658	0.4%	1,658	0%
Pasture	12,053	3%	603	95%
Forest	332,924	74%	332,924	0%
Residential	104,681	23%	10,468	90%
Total	451,315	100%	345,652	23%

Table G-2b. Required annual reductions in direct nonpoint sources in sub-watershed PGG-2.

Source	Current Conditions load (x 10^8 cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cattle in Streams	0	0%	0	100%
Wildlife in Streams	33,956	100%	23,769	30%
Straight Pipes	0	0%	0	100%
Total	33,956	100%	23,769	30%

Table G-3a. Required annual reductions in nonpoint sources in sub-watershed PGG-3.

Land Use	Current conditions load (x 10^8 cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cropland	95,527	0.1%	95,527	0%
Pasture	114,940,787	100%	5,747,041	95%
Forest	134,792	0.1%	134,792	0%
Residential	80,209	0.1%	8,021	90%
Total	115,251,314	100%	5,985,380	95%

Table G-3b. Required annual reductions in direct nonpoint sources in sub-watershed PGG-3.

Source	Current Conditions load (x 10^8 cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cattle in Streams	0	0%	0	100%
Wildlife in Streams	7,129	100%	4,990	30%
Straight Pipes	0	0%	0	100%
Total	7,129	100%	4,990	30%

Table G-4a. Required annual reductions in nonpoint sources in sub-watershed PGG-4.

Land Use	Current conditions load (x 10^8 cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cropland	65,130	1%	65,130	0%
Pasture	3,615,616	63%	180,781	95%
Forest	1,426,992	25%	1,426,992	0%
Residential	669,540	12%	66,954	90%
Total	5,777,278	100%	1,739,857	70%

Table G-4b. Required annual reductions in direct nonpoint sources in sub-watershed PGG-4.

Source	Current Conditions load (x 10^8 cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cattle in Streams	22,268	13%	0	100%
Wildlife in Streams	146,952	87%	102,866	30%
Straight Pipes	0	0%	0	100%
Total	169,219	100%	102,866	39%

Table G-5a. Required annual reductions in nonpoint sources in sub-watershed PGG-5.

Land Use	Current conditions load (x 10^8 cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cropland	4,221	0.4%	4,221	0%
Pasture	960,108	84%	48,005	95%
Forest	131,978	12%	131,978	0%
Residential	46,350	4%	4,635	90%
Total	1,142,657	100%	188,840	83%

Table G-5b. Required annual reductions in direct nonpoint sources in sub-watershed PGG-5.

Source	Current Conditions load (x 10^8 cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cattle in Streams	0	0%	0	100%
Wildlife in Streams	6,215	100%	4,350	30%
Straight Pipes	0	0%	0	100%
Total	6,215	100%	4,350	30%

Table G-6a. Required annual reductions in nonpoint sources in sub-watershed PGG-6.

Land Use	Current conditions load (x 10^8 cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cropland	22,090	1%	22,090	0%
Pasture	135,107	8%	6,755	95%
Forest	959,656	58%	959,656	0%
Residential	542,762	33%	54,276	90%
Total	1,659,614	100%	1,042,777	37%

Table G-6b. Required annual reductions in direct nonpoint sources in sub-watershed PGG-6.

Source	Current Conditions load (x 10^8 cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cattle in Streams	0	0%	0	100%
Wildlife in Streams	53,754	100%	37,628	30%
Straight Pipes	0	0%	0	100%
Total	53,754	100%	37,628	30%

Table G-7a. Required annual reductions in nonpoint sources in sub-watershed PGG-7.

Land Use	Current conditions load (x 10^8 cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cropland	264,547	1%	264,547	0%
Pasture	20,557,566	84%	1,027,879	95%
Forest	2,359,387	10%	2,359,387	0%
Residential	1,237,978	5%	123,798	90%
Total	24,419,478	100%	3,775,610	85%

Table G-7b. Required annual reductions in direct nonpoint sources in sub-watershed PGG-7.

Source	Current Conditions load (x 10^8 cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cattle in Streams	277,110	69%	0	100%
Wildlife in Streams	126,603	31%	88,622	30%
Straight Pipes	0	0%	0	100%
Total	403,713	100%	88,622	78%

Table G-8a. Required annual reductions in nonpoint sources in sub-watershed PGG-8.†

Land Use	Current conditions load (x 10^8 cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cropland	6,799	3%	6,799	0%
Pasture	17,163	9%	858	95%
Forest	127,552	64%	127,552	0%
Residential	47,921	24%	2,396	95%
Total	199,435	100%	137,605	31%

†Sub-watershed is part of Snow Creek

Table G-8b. Required annual reductions in direct nonpoint sources in sub-watershed PGG-8.†

Source	Current Conditions load (x 10^8 cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cattle in Streams	0	0%	0	60%
Wildlife in Streams	7,013	100%	7,013	0%
Straight Pipes	0	0%	0	100%
Total	7,013	100%	7,013	0%

†Sub-watershed is part of Snow Creek

Table G-9a. Required annual reductions in nonpoint sources in sub-watershed PGG-9.

Land Use	Current conditions load (x 10^8 cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cropland	273,517	0.4%	273,517	0%
Pasture	59,400,976	88%	2,970,050	95%
Forest	5,089,765	8%	5,089,765	0%
Residential	2,889,675	4%	288,968	90%
Total	67,653,933	100%	8,622,299	87%

Table G-9b. Required annual reductions in direct nonpoint sources in sub-watershed PGG-9.

Source	Current Conditions load (x 10^8 cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cattle in Streams	696,733	56%	0	100%
Wildlife in Streams	555,413	44%	388,789	30%
Straight Pipes	0	0%	0	100%
Total	1,252,146	100%	388,789	69%

Table G-10a. Required annual reductions in nonpoint sources in sub-watershed PGG-10.†

Land Use	Current conditions load (x 10^8 cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cropland	114,085	0.2%	114,085	0%
Pasture	41,513,313	91%	2,075,666	95%
Forest	2,508,800	5%	2,508,800	0%
Residential	1,711,342	4%	85,567	95%
Total	45,847,540	100%	4,784,118	90%

†Sub-watershed is part of Snow Creek

Table G-10b. Required annual reductions in direct nonpoint sources in sub-watershed PGG-10.†

Source	Current Conditions load (x 10^8 cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cattle in Streams	880,813	86%	352,325	60%
Wildlife in Streams	130,915	13%	130,915	0%
Straight Pipes	17,970	2%	0	100%
Total	1,029,699	100%	483,241	53%

†Sub-watershed is part of Snow Creek

Table G-11a. Required annual reductions in nonpoint sources in sub-watershed PGG-11.†

Land Use	Current conditions load (x 10^8 cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cropland	1,612,981	5%	1,612,981	0%
Pasture	22,935,855	70%	1,146,793	95%
Forest	5,348,033	16%	5,348,033	0%
Residential	2,834,596	9%	141,730	95%
Total	32,731,464	100%	8,249,537	75%

†Sub-watershed is part of Snow Creek

Table G-11b. Required annual reductions in direct nonpoint sources in sub-watershed PGG-11.†

Source	Current Conditions load (x 10^8 cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cattle in Streams	227,626	44%	91,050	60%
Wildlife in Streams	274,797	53%	274,797	0%
Straight Pipes	18,116	3%	0	100%
Total	520,539	100%	365,847	30%

†Sub-watershed is part of Snow Creek

Table G-12a. Required annual reductions in nonpoint sources in sub-watershed PGG-12.†

Land Use	Current conditions load (x 10^8 cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cropland	579,244	0.8%	579,244	0%
Pasture	62,438,984	85%	3,121,950	95%
Forest	6,401,970	9%	6,401,970	0%
Residential	3,946,344	5%	197,317	95%
Total	73,366,541	100%	10,300,481	86%

†Sub-watershed is part of Snow Creek

Table G-12b. Required annual reductions in direct nonpoint sources in sub-watershed PGG-12.†

Source	Current Conditions load (x 10^8 cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cattle in Streams	950,090	73%	380,036	60%
Wildlife in Streams	341,780	26%	341,780	0%
Straight Pipes	17,751	1%	0	100%
Total	1,309,621	100%	721,816	45%

†Sub-watershed is part of Snow Creek

Table G-13a. Required annual reductions in nonpoint sources in sub-watershed PGG-13.

Land Use	Current conditions load (x 10^8 cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cropland	4,698	0.5%	4,698	0%
Pasture	40,713	4%	2,036	95%
Forest	390,084	41%	390,084	0%
Residential	520,664	54%	52,066	90%
Total	956,158	100%	448,884	53%

Table G-13b. Required annual reductions in direct nonpoint sources in sub-watershed PGG-13.

Source	Current Conditions load (x 10^8 cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cattle in Streams	0	0%	0	100%
Wildlife in Streams	42,260	100%	29,582	30%
Straight Pipes	0	0%	0	100%
Total	42,260	100%	29,582	30%

Table G-14a. Required annual reductions in nonpoint sources in sub-watershed PGG-14.

Land Use	Current conditions load (x 10^8 cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cropland	27,459	0.3%	27,459	0%
Pasture	5,750,700	61%	287,535	95%
Forest	2,231,939	24%	2,231,939	0%
Residential	1,460,270	15%	146,027	90%
Total	9,470,367	100%	2,692,960	72%

Table G-14b. Required annual reductions in direct nonpoint sources in sub-watershed PGG-14.

Source	Current Conditions load (x 10^8 cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cattle in Streams	23,752	17%	0	100%
Wildlife in Streams	116,722	83%	81,705	30%
Straight Pipes	0	0%	0	100%
Total	140,474	100%	81,705	42%

Table G-15a. Required annual reductions in nonpoint sources in sub-watershed PGG-15.

Land Use	Current conditions load (x 10^8 cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cropland	873,195	1%	873,195	0%
Pasture	52,690,820	84%	2,634,542	95%
Forest	2,846,287	5%	2,846,287	0%
Residential	5,982,211	10%	598,221	90%
Total	62,392,512	100%	6,952,245	89%

Table G-15b. Required annual reductions in direct nonpoint sources in sub-watershed PGG-15.

Source	Current Conditions load (x 10^8 cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cattle in Streams	657,380	64%	0	100%
Wildlife in Streams	333,871	33%	233,710	30%
Straight Pipes	35,648	3%	0	100%
Total	1,026,900	100%	233,710	77%

Table G-16a. Required annual reductions in nonpoint sources in sub-watershed PGG-16.

Land Use	Current conditions load (x 10^8 cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cropland	58,701	0.3%	58,701	0%
Pasture	15,185,499	74%	759,275	95%
Forest	1,619,211	8%	1,619,211	0%
Residential	3,596,872	18%	359,687	90%
Total	20,460,283	100%	2,796,874	86%

Table G-16b. Required annual reductions in direct nonpoint sources in sub-watershed PGG-16.

Source	Current Conditions load (x 10^8 cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cattle in Streams	237,523	73%	0	100%
Wildlife in Streams	86,395	27%	60,477	30%
Straight Pipes	0	0%	0	100%
Total	323,918	100%	60,477	81%

Table G-17a. Required annual reductions in nonpoint sources in sub-watershed PGG-17.

Land Use	Current conditions load (x 10^8 cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cropland	37,948	0.3%	37,948	0%
Pasture	5,878,860	53%	293,943	95%
Forest	2,412,569	22%	2,412,569	0%
Residential	2,801,066	25%	280,107	90%
Total	11,130,442	100%	3,024,566	73%

Table G-17b. Required annual reductions in direct nonpoint sources in sub-watershed PGG-17.

Source	Current Conditions load (x 10^8 cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cattle in Streams	0	0%	0	100%
Wildlife in Streams	123,841	100%	86,689	30%
Straight Pipes	0	0%	0	100%
Total	123,841	100%	86,689	30%

Table G-18a. Required annual reductions in nonpoint sources in sub-watershed PGG-18.

Land Use	Current conditions load (x 10^8 cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cropland	61,371	0.3%	61,371	0%
Pasture	11,627,429	56%	581,372	95%
Forest	4,915,530	24%	4,915,530	0%
Residential	4,061,836	20%	406,184	90%
Total	20,666,166	100%	5,964,456	71%

Table G-18b. Required annual reductions in direct nonpoint sources in sub-watershed PGG-18.

Source	Current Conditions load (x 10^8 cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cattle in Streams	47,505	14%	0	100%
Wildlife in Streams	261,649	76%	183,154	30%
Straight Pipes	35,941	10%	0	100%
Total	345,094	100%	183,154	47%

Table G-19a. Required annual reductions in nonpoint sources in sub-watershed PGG-19.

Land Use	Current conditions load (x 10^8 cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cropland	14,762	0%	14,762	0%
Pasture	24,333,672	74%	1,216,684	95%
Forest	1,715,547	5%	1,715,547	0%
Residential	6,823,126	21%	682,313	90%
Total	32,887,107	100%	3,629,306	89%

Table G-19b. Required annual reductions in direct nonpoint sources in sub-watershed PGG-19.

Source	Current Conditions load (x 10^8 cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cattle in Streams	318,433	70%	0	100%
Wildlife in Streams	83,538	18%	79,361	5%
Straight Pipes	53,034	12%	0	100%
Total	455,005	100%	79,361	83%

Table G-20a. Required annual reductions in nonpoint sources in sub-watershed PGG-20.

Land Use	Current conditions load (x 10^8 cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cropland	173,599	0.5%	173,599	0%
Pasture	30,043,858	85%	1,502,193	95%
Forest	1,164,386	3%	1,164,386	0%
Residential	3,858,136	11%	385,814	90%
Total	35,239,979	100%	3,225,992	91%

Table G-20b. Required annual reductions in direct nonpoint sources in sub-watershed PGG-20.

Source	Current Conditions load (x 10^8 cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cattle in Streams	442,940	84%	0	100%
Wildlife in Streams	63,807	12%	60,617	5%
Straight Pipes	18,628	4%	0	100%
Total	525,375	100%	60,617	88%

Table G-21a. Required annual reductions in nonpoint sources in sub-watershed PGG-21.†

Land Use	Current conditions load (x 10^8 cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cropland	87,288	0.3%	87,288	0%
Pasture	26,391,412	80%	3,958,711	85%
Forest	2,239,682	7%	2,239,682	0%
Residential	4,252,387	13%	1,063,097	75%
Total	32,970,769	100%	7,348,779	78%

†Sub-watershed is part of Story Creek

Table G-21b. Required annual reductions in direct nonpoint sources in sub-watershed PGG-21.†

Source	Current Conditions load (x 10^8 cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cattle in Streams	358,219	74%	0	100%
Wildlife in Streams	110,350	23%	60,693	45%
Straight Pipes	18,409	4%	0	100%
Total	486,978	100%	60,693	88%

†Sub-watershed is part of Story Creek

Table G-22a. Required annual reductions in nonpoint sources in sub-watershed PGG-22.

Land Use	Current conditions load (x 10^8 cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cropland	437,208	1.0%	437,208	0%
Pasture	36,814,334	83%	1,840,717	95%
Forest	4,214,642	10%	4,214,642	0%
Residential	2,819,730	6%	281,973	90%
Total	44,285,914	100%	6,774,541	85%

Table G-22b. Required annual reductions in direct nonpoint sources in sub-watershed PGG-22.

Source	Current Conditions load (x 10^8 cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cattle in Streams	212,274	49%	0	100%
Wildlife in Streams	199,938	46%	189,941	5%
Straight Pipes	18,701	4%	0	100%
Total	430,913	100%	189,941	56%

Table G-23a. Required annual reductions in nonpoint sources in sub-watershed PGG-23.†

Land Use	Current conditions load (x 10^8 cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cropland	1,477	0%	1,477	0%
Pasture	1,871,983	50%	280,797	85%
Forest	227,951	6%	227,951	0%
Residential	1,622,915	44%	405,729	75%
Total	3,724,327	100%	915,954	75%

†Sub-watershed is part of Story Creek

Table G-23b. Required annual reductions in direct nonpoint sources in sub-watershed PGG-23.†

Source	Current Conditions load (x 10^8 cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cattle in Streams	39,587	59%	0	100%
Wildlife in Streams	9,381	14%	5,160	45%
Straight Pipes	18,043	27%	0	100%
Total	67,012	100%	5,160	92%

†Sub-watershed is part of Story Creek

Table G-24a. Required annual reductions in nonpoint sources in sub-watershed OWC-1.

Land Use	Current conditions load (x 10^8 cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cropland	13	0%	13	0%
Pasture	982	3%	98	90%
Forest	15,843	41%	15,843	0%
Residential	21,623	56%	0	100%
Total	38,461	100%	15,955	59%

Table G-24b. Required annual reductions in direct nonpoint sources in sub-watershed OWC-1.

Source	Current Conditions load (x 10^8 cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cattle in Streams	0	0%	0	100%
Wildlife in Streams	840	100%	277	67%
Total	840	100%	277	67%

Table G-25a. Required annual reductions in nonpoint sources in sub-watershed OWC-2.

Land Use	Current conditions load (x 10^8 cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cropland	856	0.4%	856	0%
Pasture	4,449	2%	445	90%
Forest	97,784	45%	97,784	0%
Residential	116,076	53%	17,411	85%
Total	219,166	100%	116,496	47%

Table G-25b. Required annual reductions in direct nonpoint sources in sub-watershed OWC-2.

Source	Current Conditions load (x 10^8 cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cattle in Streams	0	0%	0	100%
Wildlife in Streams	5,490	100%	1,812	67%
Total	5,490	100%	1,812	67%

Table G-26a. Required annual reductions in nonpoint sources in sub-watershed OWC-3.

Land Use	Current conditions load (x 10^8 cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cropland	113	0.4%	113	0%
Pasture	8,330	27%	833	90%
Forest	20,408	67%	20,408	0%
Residential	1,644	5%	0	100%
Total	30,495	100%	21,354	30%

Table G-26b. Required annual reductions in direct nonpoint sources in sub-watershed OWC-3.

Source	Current Conditions load (x 10^8 cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cattle in Streams	0	0%	0	100%
Wildlife in Streams	1,122	100%	370	67%
Total	1,122	100%	370	67%

Table G-27a. Required annual reductions in nonpoint sources in sub-watershed OWC-4.

Land Use	Current conditions load (x 10^8 cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cropland	22,938	0.6%	22,938	0%
Pasture	3,357,541	81%	335,754	90%
Forest	447,294	11%	447,294	0%
Residential	318,388	8%	47,758	85%
Total	4,146,162	100%	853,744	79%

Table G-27b. Required annual reductions in direct nonpoint sources in sub-watershed OWC-4.

Source	Current Conditions load (x 10^8 cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cattle in Streams	26,986	54%	0	100%
Wildlife in Streams	22,703	46%	7,492	67%
Total	49,689	100%	7,492	85%

Table G-28a. Required annual reductions in nonpoint sources in sub-watershed OWC-5.

Land Use	Current conditions load (x 10^8 cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cropland	34,441	0.5%	34,441	0%
Pasture	6,040,980	89%	604,098	90%
Forest	359,090	5%	359,090	0%
Residential	326,862	5%	49,029	85%
Total	6,761,373	100%	1,046,658	85%

Table G-28b. Required annual reductions in direct nonpoint sources in sub-watershed OWC-5.

Source	Current Conditions load (x 10^8 cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cattle in Streams	6,698	29%	0	100%
Wildlife in Streams	16,778	71%	5,537	67%
Total	23,477	100%	5,537	76%

Table G-29a. Required annual reductions in nonpoint sources in sub-watershed OWC-6.

Land Use	Current conditions load (x 10^8 cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cropland	5,885	0.5%	5,885	0%
Pasture	665,958	62%	66,596	90%
Forest	321,393	30%	321,393	0%
Residential	86,236	8%	12,935	85%
Total	1,079,471	100%	406,809	62%

Table G-29b. Required annual reductions in direct nonpoint sources in sub-watershed OWC-6.

Source	Current Conditions load (x 10^8 cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cattle in Streams	7,228	33%	0	100%
Wildlife in Streams	14,798	67%	4,883	67%
Total	22,027	100%	4,883	78%

Table G-30a. Required annual reductions in nonpoint sources in sub-watershed OWC-7.

Land Use	Current conditions load (x 10^8 cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cropland	3,838	0.4%	3,838	0%
Pasture	727,382	67%	72,738	90%
Forest	294,908	27%	294,908	0%
Residential	53,107	5%	7,966	85%
Total	1,079,234	100%	379,450	65%

Table G-30b. Required annual reductions in direct nonpoint sources in sub-watershed OWC-7.

Source	Current Conditions load (x 10^8 cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cattle in Streams	16,384	52%	0	100%
Wildlife in Streams	14,961	48%	4,937	67%
Total	31,345	100%	4,937	84%

Appendix H: Simulated Stream Flow Charts for TMDL Allocation Period

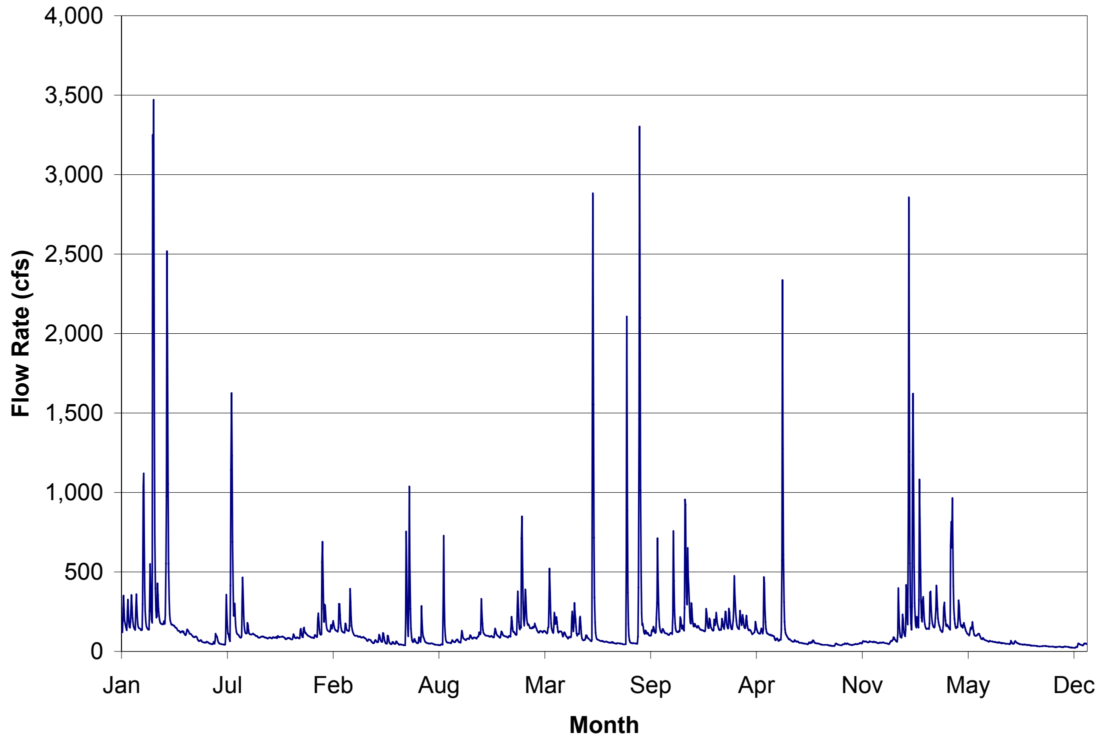

Figure H.1. Simulated stream flow for Snow Creek.

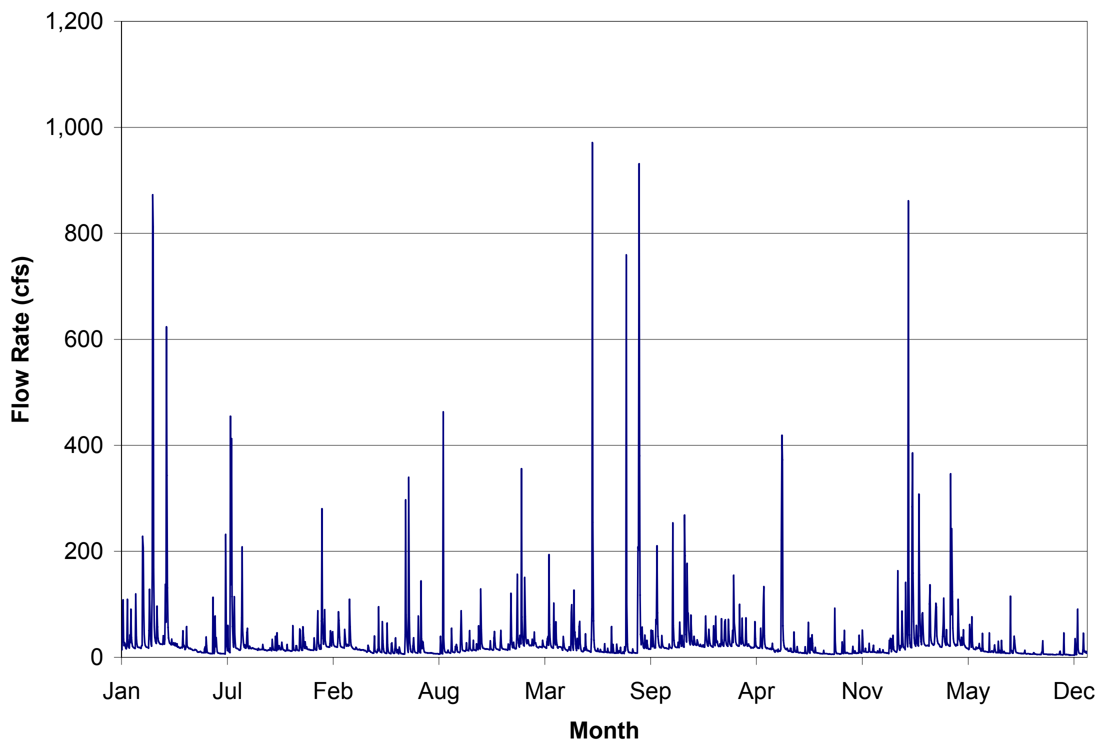

Figure H.2. Simulated stream flow for Story Creek.

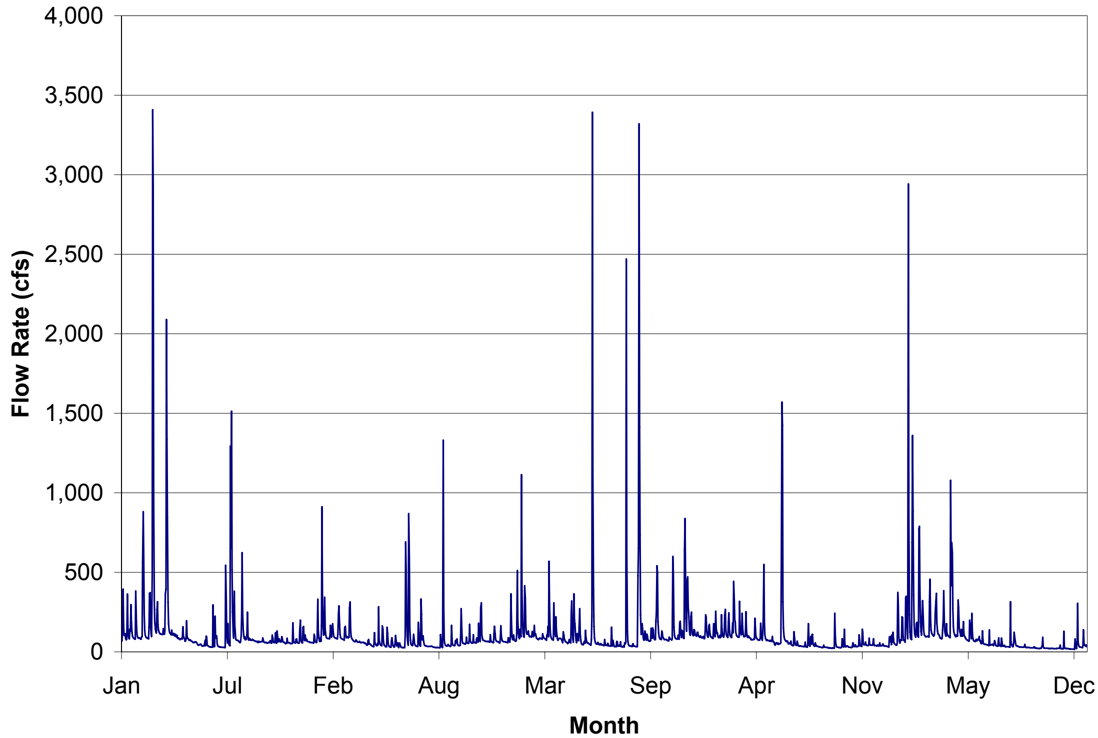

Figure H.3. Simulated stream flow for Upper Pigg River.

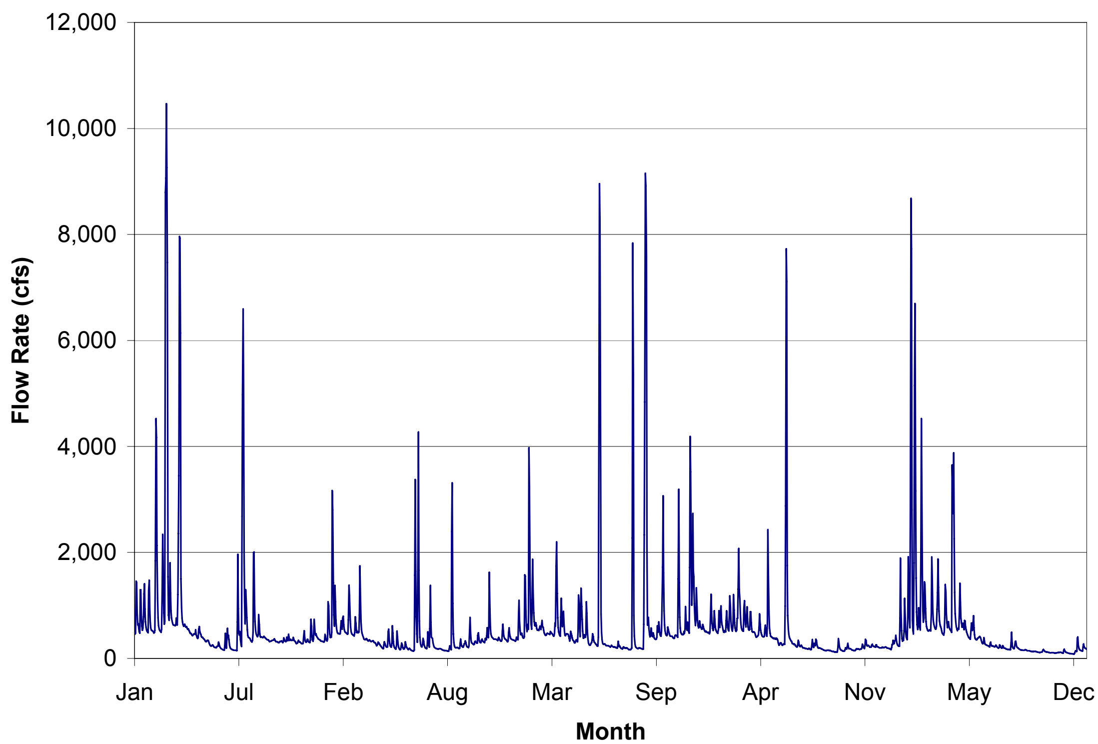

Figure H.4. Simulated stream flow for LL-Pigg River.

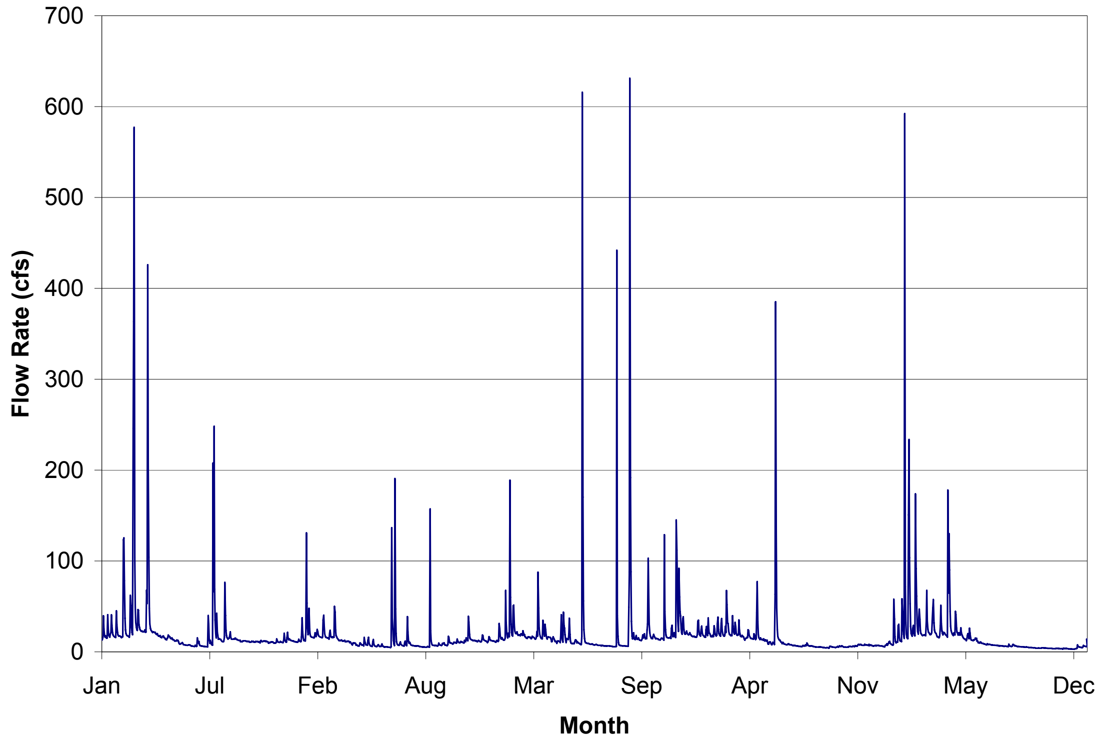

Figure H.5. Simulated stream flow for Old Womans Creek.

Appendix I: Observed Fecal Coliform Concentrations and Antecedent Rainfall

This appendix presents the observed fecal coliform concentrations and antecedent rainfall for the six stations that caused the impairment listings (Table I.1).

Table I.1. Observed fecal coliform concentrations and antecedent rainfall for the listing stations for Pigg River and Old Womans Creek.

Station	Date	Fecal Coliform Concentration (cfu/100mL)	Total Rainfall for Sampling Day and Preceding 5 days (inches)
		Snow Creek	
4ASNW000.60	1/26/1998	400	1.5
4ASNW000.60	4/20/1998	8000	4
4ASNW000.60	7/21/1998	8000	0.9
4ASNW000.60	10/19/1998	200	0
4ASNW000.60	1/12/1999	100	0
4ASNW000.60	4/8/1999	200	0
4ASNW000.60	10/7/1999	100	0.1
4ASNW000.60	12/20/1999	100	0.2
4ASNW000.60	2/10/2000	100	0
4ASNW000.60	4/6/2000	100	0.4
4ASNW000.60	6/20/2000	1500	1.7
4ASNW000.60	8/10/2000	100	0.7
4ASNW000.60	10/10/2000	200	0
4ASNW000.60	12/14/2000	100	0.1
4ASNW000.60	2/5/2001	100	0
4ASNW000.60	4/9/2001	300	0
4ASNW000.60	6/19/2001	100	0
		Story Creek	
4ASDA009.79	1/21/1998	100	0.2
4ASDA009.79	4/14/1998	700	0.7
4ASDA009.79	7/14/1998	100	0.4
4ASDA009.79	10/27/1998	700	0
4ASDA009.79	2/2/1999	400	1.1
4ASDA009.79	4/14/1999	600	1.6
4ASDA009.79	7/22/1999	8000	1
4ASDA009.79	9/20/1999	100	0.5
4ASDA009.79	12/7/1999	600	0.2
4ASDA009.79	2/8/2000	100	0.1
4ASDA009.79	4/3/2000	200	0.2
4ASDA009.79	6/20/2000	1600	1.7
4ASDA009.79	7/19/2000	2200	0
4ASDA009.79	8/10/2000	3700	0.7
4ASDA009.79	9/14/2000	1100	0
4ASDA009.79	5/7/2001	2200	0.3
4ASDA009.79	9/24/2001	8000	1.2
4ASDA009.79	10/24/2001	500	0
4ASDA009.79	12/17/2001	100	0.4

Station	Date	Fecal Coliform Concentration (cfu/100mL)	Total Rainfall for Sampling Day and Preceding 5 days (inches)
4ASDA009.79	2/26/2002	100	0
4ASDA009.79	4/4/2002	100	1.6
4ASDA009.79	6/10/2002	1100	0.3
4ASDA009.79	8/20/2002	100	0
4ASDA009.79	10/22/2002	200	0.3
Leesville Lake-Pigg River			
4APGG003.29	1/26/1998	1300	1.5
4APGG003.29	4/20/1998	8000	4
4APGG003.29	7/21/1998	200	0.9
4APGG003.29	10/19/1998	100	0
4APGG003.29	1/12/1999	400	0
4APGG003.29	4/8/1999	100	0
4APGG003.29	8/10/1999	100	0.2
4APGG003.29	10/7/1999	400	0.1
4APGG003.29	12/20/1999	200	0.2
4APGG003.29	2/10/2000	100	0
4APGG003.29	4/6/2000	100	0.4
4APGG003.29	6/20/2000	200	1.7
4APGG003.29	8/10/2000	8000	0.7
4APGG003.29	10/10/2000	500	0
4APGG003.29	12/14/2000	100	0.1
4APGG003.29	2/5/2001	100	0
4APGG003.29	4/9/2001	100	0
4APGG003.29	6/19/2001	100	0
Lower Pigg River			
4APGG030.62	1/29/1998	2200	3.4
4APGG030.62	3/30/1998	100	0
4APGG030.62	7/13/1998	100	0.6
4APGG030.62	10/22/1998	100	0
4APGG030.62	1/25/1999	3600	1.5
4APGG030.62	4/12/1999	8000	1.6
4APGG030.62	8/10/1999	100	0.2
4APGG030.62	10/7/1999	500	0.1
4APGG030.62	12/20/1999	100	0.2
4APGG030.62	2/10/2000	100	0
4APGG030.62	4/6/2000	200	0.4
4APGG030.62	6/20/2000	1100	1.7
4APGG030.62	8/10/2000	200	0.7
4APGG030.62	10/10/2000	100	0
4APGG030.62	12/14/2000	100	0.1
4APGG030.62	2/5/2001	100	0
4APGG030.62	4/9/2001	100	0
4APGG030.62	6/19/2001	300	0
4APGG030.62	7/26/2001	100	1
4APGG030.62	9/4/2001	300	0.1
4APGG030.62	11/29/2001	100	0.5

Station	Date	Fecal Coliform Concentration (cfu/100mL)	Total Rainfall for Sampling Day and Preceding 5 days (inches)
4APGG030.62	1/10/2002	200	0.5
4APGG030.62	3/14/2002	100	0.7
4APGG030.62	5/15/2002	500	0.8
4APGG030.62	7/16/2002	100	0.8
4APGG030.62	9/19/2002	200	0.9
4APGG030.62	11/18/2002	3900	1.8
Upper Pigg River			
4APGG052.73	1/21/1998	200	0.2
4APGG052.73	2/11/1998	100	0.6
4APGG052.73	3/9/1998	8000	1.9
4APGG052.73	4/14/1998	200	0.7
4APGG052.73	5/26/1998	1300	1.5
4APGG052.73	6/8/1998	400	0.3
4APGG052.73	7/14/1998	100	0.4
4APGG052.73	8/24/1998	100	0
4APGG052.73	9/23/1998	100	0.2
4APGG052.73	10/27/1998	300	0
4APGG052.73	11/9/1998	100	0.4
4APGG052.73	12/3/1998	100	0
4APGG052.73	1/5/1999	700	1.6
4APGG052.73	1/11/1999	2800	0
4APGG052.73	2/2/1999	4500	1.1
4APGG052.73	3/17/1999	100	1.5
4APGG052.73	4/14/1999	1100	1.6
4APGG052.73	5/5/1999	300	0
4APGG052.73	6/9/1999	100	0
4APGG052.73	7/22/1999	8000	1
4APGG052.73	8/11/1999	100	0.2
4APGG052.73	9/20/1999	700	0.5
4APGG052.73	11/17/1999	100	0
4APGG052.73	12/15/1999	8000	1.6
4APGG052.73	2/15/2000	100	0.5
4APGG052.73	3/1/2000	100	0.2
4APGG052.73	4/12/2000	300	0.3
4APGG052.73	5/18/2000	100	0
4APGG052.73	6/13/2000	100	0.2
4APGG052.73	7/19/2000	100	0
4APGG052.73	8/10/2000	100	0.7
4APGG052.73	9/14/2000	900	0
4APGG052.73	10/10/2000	100	0
4APGG052.73	11/20/2000	100	0
4APGG052.73	12/14/2000	100	0.1
4APGG052.73	1/22/2001	100	1.7
4APGG052.73	2/5/2001	100	0
4APGG052.73	4/9/2001	300	0
4APGG052.73	5/7/2001	1300	0.3

Station	Date	Fecal Coliform Concentration (cfu/100mL)	Total Rainfall for Sampling Day and Preceding 5 days (inches)
4APGG052.73	6/19/2001	100	0
4APGG052.73	7/26/2001	300	1
4APGG052.73	9/4/2001	100	0.1
4APGG052.73	9/24/2001	8000	1.2
4APGG052.73	10/24/2001	100	0
4APGG052.73	11/29/2001	200	0.5
4APGG052.73	12/17/2001	100	0.4
4APGG052.73	1/10/2002	100	0.5
4APGG052.73	2/26/2002	100	0
4APGG052.73	3/14/2002	100	0.7
4APGG052.73	4/4/2002	100	1.6
4APGG052.73	5/15/2002	2400	0.8
4APGG052.73	6/10/2002	100	0.3
4APGG052.73	7/16/2002	200	0.8
4APGG052.73	8/20/2002	100	0
4APGG052.73	9/19/2002	900	0.9
4APGG052.73	10/22/2002	300	0.3
4APGG052.73	11/18/2002	1000	1.8
Old Womans Creek			
4AOWC005.36	3/9/1998	200	1.9
4AOWC005.36	6/22/1998	100	0
4AOWC005.36	9/15/1998	400	0
4AOWC005.36	12/7/1998	100	0
4AOWC005.36	3/11/1999	100	0.2
4AOWC005.36	6/1/1999	1700	0
4AOWC005.36	8/23/1999	300	0.608
4AOWC005.36	10/27/1999	400	0
4AOWC005.36	12/15/1999	100	1.6
4AOWC005.36	2/8/2000	100	0.1
4AOWC005.36	6/19/2000	100	1
4AOWC005.36	8/3/2000	100	0.5
4AOWC005.36	10/26/2000	6000	0
4AOWC005.36	12/18/2000	100	0.9
4AOWC005.36	2/14/2001	100	0.3
4AOWC005.36	4/10/2001	800	0
4AOWC005.36	6/11/2001	100	1

Appendix J: Scenarios for Fivefold Increase in Permitted Discharge Flows

To allow for future growth, a scenario was created for Pigg River and Old Womans Creek in which the point source flows were increased by a factor of 5, while retaining the 126 cfu/100 mL limit on *E. coli* bacteria. This effectively increased the WLA by a factor of 5. This scenario was also applied to the <1% allowance for future conditions in watersheds currently without permitted point sources. Figures J.1-J.5 display the results for the impaired watersheds. The TMDL equations that would represent this situation are included in Table J.1.

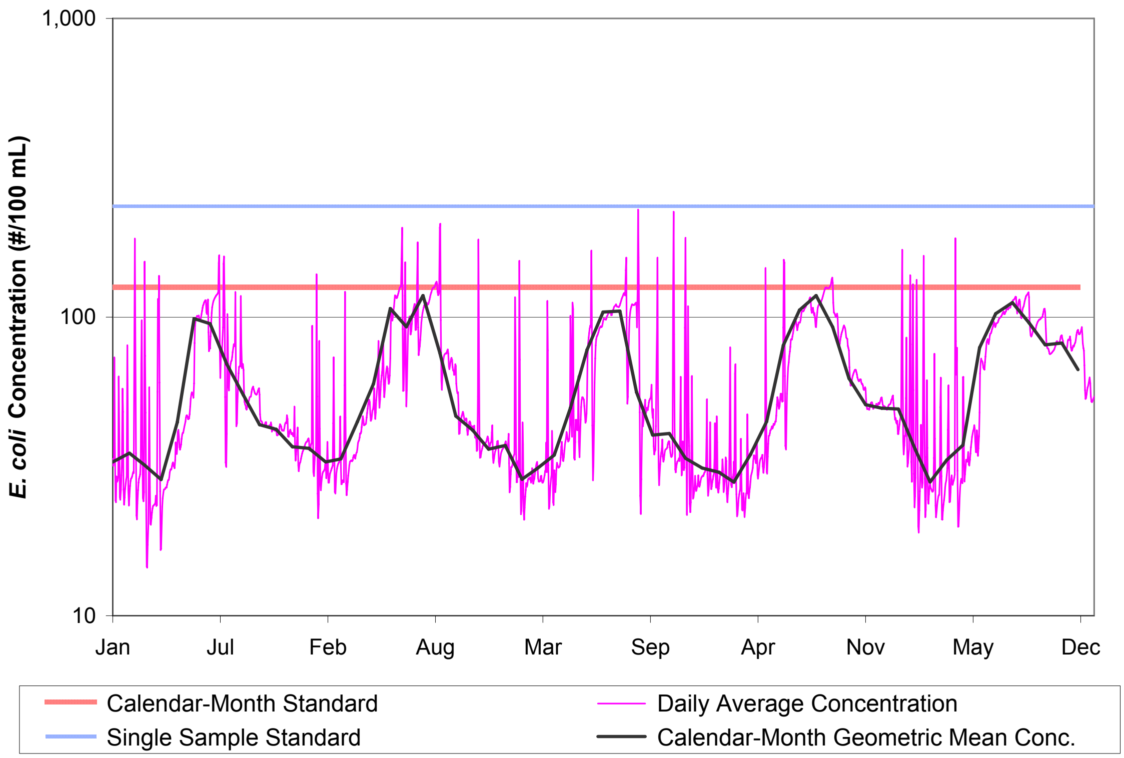

Figure J.1. Fivefold Increase Scenario for Snow Creek

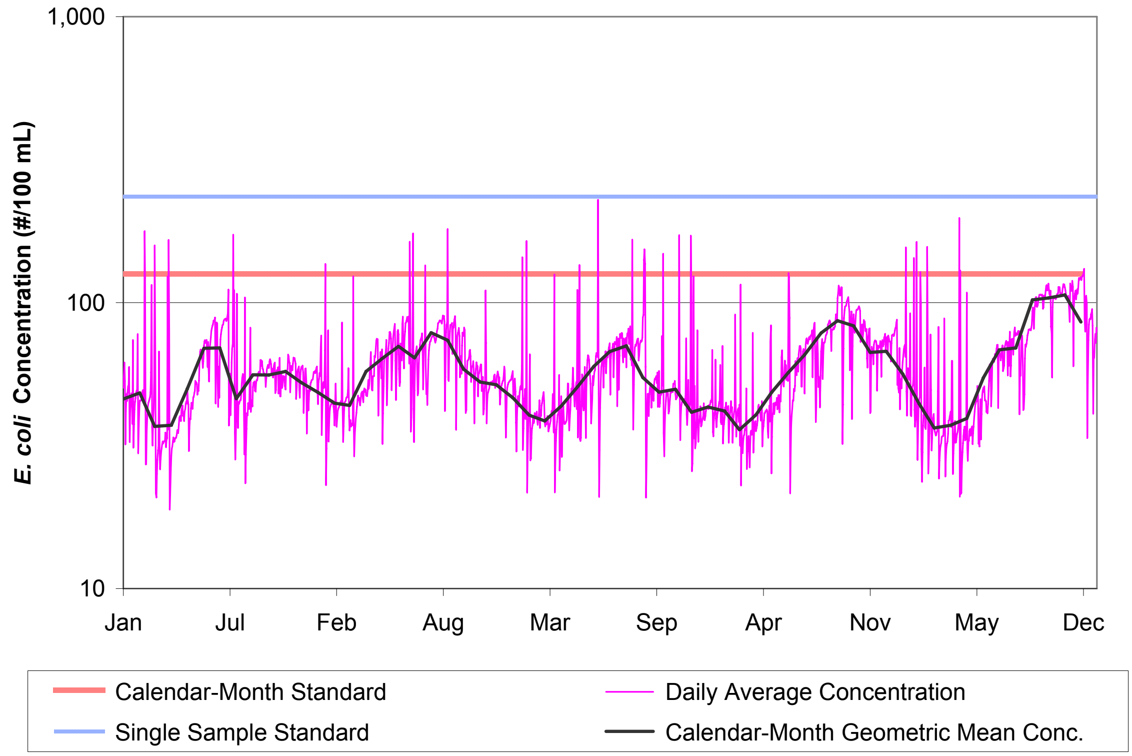

Figure J.2. Fivefold Increase Scenario for Story Creek

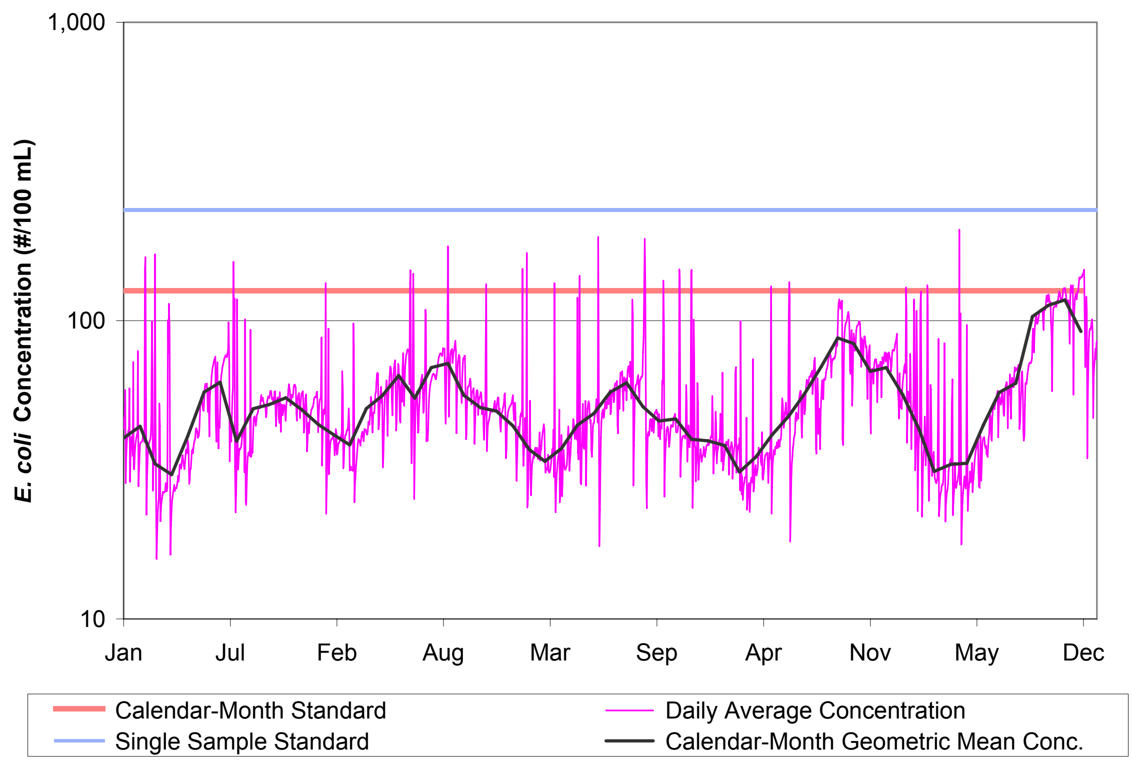

Figure J.3. Fivefold Increase Scenario for Upper Pigg River.

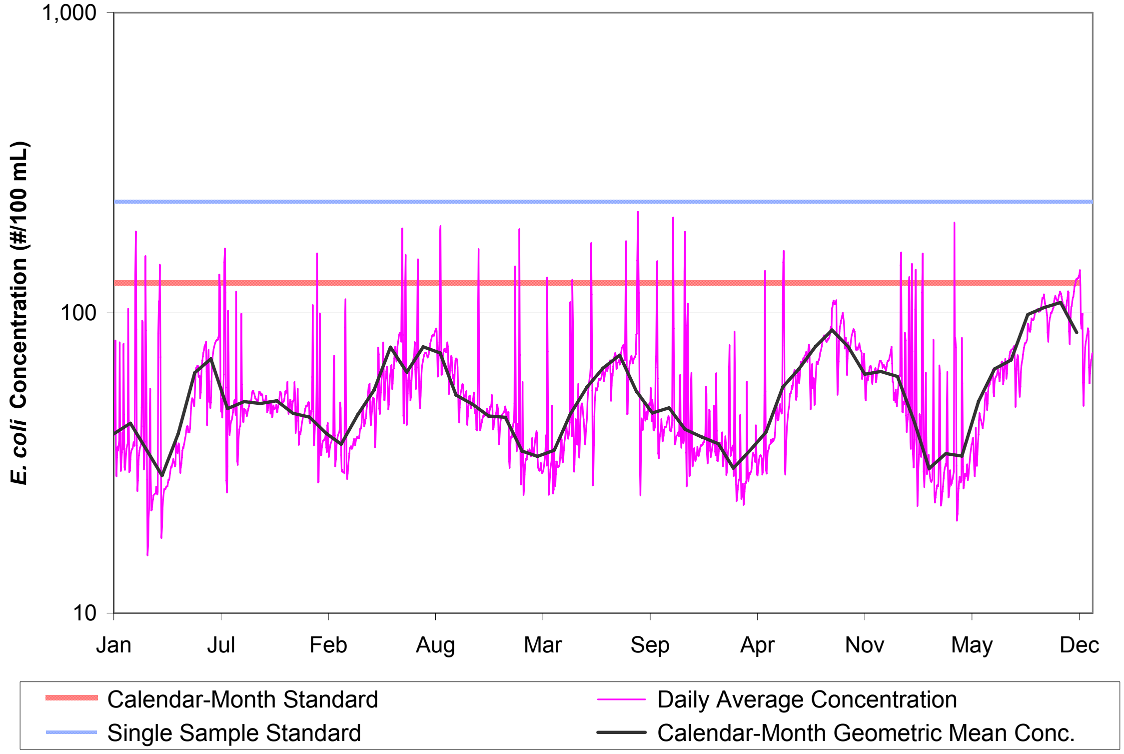

Figure J.4. Fivefold Increase Scenario for LL-Pigg River.

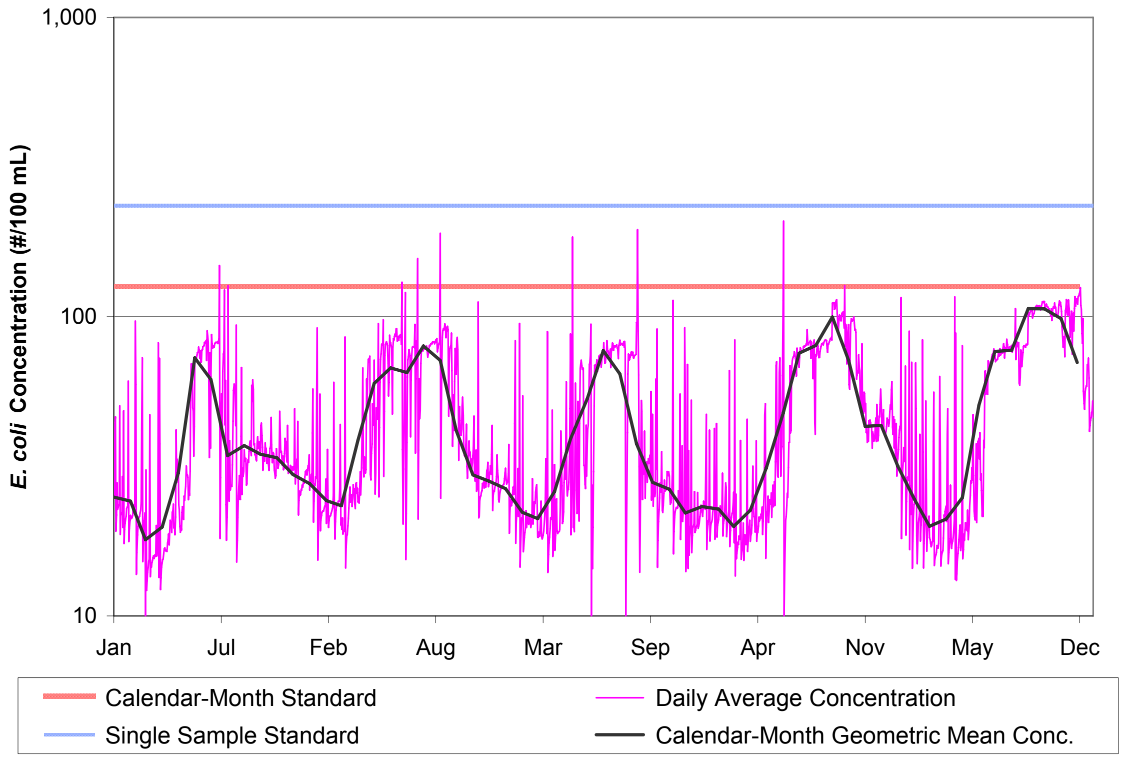

Figure J.5. Fivefold Increase Scenario for Old Womans Creek.

Table J.1. Average annual *E.coli* loadings (cfu/yr) at the watershed outlet for the Pigg River and Old Womans Creek watersheds under the fivefold WLA increase scenario.

Watershed	WLA	LA	MOS*	TMDL
Snow Creek	<5%	8.31×10^{13}	--	8.73×10^{13}
Story Creek	3.50×10^{12}	1.84×10^{13}	--	2.19×10^{13}
Upper Pigg	5.91×10^{12}	6.57×10^{13}	--	7.16×10^{13}
Upper Pigg excluding Story Creek	<5%	4.73×10^{13}	--	4.97×10^{13}
LL – Pigg River	3.12×10^{13}	3.26×10^{14}	--	3.57×10^{14}
LL – Pigg River excluding Snow Cr, Story Cr, and Upper Pigg	2.11×10^{13}	1.77×10^{14}	--	1.98×10^{14}
Old Womans Creek	<5%	6.99×10^{12}	--	7.35×10^{12}

*Implicit MOS

As can be seen from Figures J.1-J.5, the new scenario results in no violations of the single sample or geometric mean standard. Therefore, it is assumed that future growth in point source dischargers with a consistent permitted bacteria concentration of 126 cfu/100 mL *E. coli* will not cause additional violations of the water quality standards.